AR 5-5 Study

Tactical Fuel and Energy Implementation Plan

Contract Number: W91QF5-09-P-0193

24 September 2010

Prepared for:
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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* 24-10-2010	**2. REPORT TYPE** Final	**3. DATES COVERED** *(From - To)* OCT 2009 – SEP 2010

4. TITLE AND SUBTITLE AR 5-5 Study Tactical Fuel and Energy Implementation Plan	**5a. CONTRACT NUMBER** W91QF5-09-P-0193 **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Meyer, James D., and Talley, Robert E.	**5d. PROJECT NUMBER** **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Expeditionary Logistics, Inc. 13203 North Enon Church Road Chester, VA 23836	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) USA CASCOM 2221 Adams Avenue Fort Lee, VA 23801	**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution Statement A: Approved for Public Release: distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The plan provides a guideline for fuel and energy efforts in the tactical environment from now to the 2016-2028 future force timeframe. The plan establishes timelines, identifies tasks, assigns responsibilities, and establishes metrics to measure progress in meeting the energy security goals prescribed in the Army Energy Security Implementation Strategy (AESIS). The plan will be executed under the direction and governance of the Army Senior Energy Executive, ensuring the synchronization of efforts aimed at meeting the Army's overall energy security vision, mission, and goals.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: U			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Mr. James Wunderly
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	UU	119	**19b. TELEPHONE NUMBER** *(include area code)* 804-734-0038

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

This report provides the U.S. Army Combined Arms Support Command (CASCOM) and Sustainment Center of Excellence (SCoE) with a proposed Tactical Fuel and Energy Plan for the Future Force. Statements, opinions, conclusions, and recommendations in this report are those of the authors unless otherwise noted and do not necessarily represent the official position of CASCOM and SCoE or the Department of the Army.

Executive Summary

In April 2008, the Secretary of the Army commissioned the Army Energy Security Task Force (AESTF) to facilitate development of a cohesive Army-wide approach to energy security. The AESTF assessed the Army energy security posture and provided recommendations to reduce Army energy consumption, increase energy efficiency across platforms and facilities, promote the use of new sustainable sources of alternative energy, establish energy performance benchmarks and to create a culture of energy awareness across the Army based on the principles of Leadership, Partnership and Ownership.

As a result of the AESTF recommendations, the Deputy Assistant Secretary of the Army (DASA) for Energy & Partnerships (DASA (E&P)) and the Army Senior Energy Council (SEC) were established. The DASA (E&P), serving as the Army's Senior Energy Executive (SEE), produced the Army Energy Security Implementation Strategy (AESIS) which implements the AESTF guidance and communicates the Army energy security vision, mission, and goals.

The AESIS establishes five strategic energy security goals (ESG) for the Army:

- ESG 1. Reduced Energy Consumption
- ESG 2. Increased Energy Efficiency Across Platforms and Facilities
- ESG 3. Increased Use of Renewable/Alternative Energy
- ESG 4. Assured Access to Sufficient Energy Supply
- ESG 5. Reduced Adverse Impacts on the Environment

The initial list of energy security objectives (ESOs) and metrics in support of the AESIS ESGs does not adequately address operational energy requirements (See Annex A to Appendix A). This plan identifies a more comprehensive set of actionable steps and measures to establish a proactive operational energy management capability, focusing on force capabilities in the tactical environment in the 2016-2028 timeframe.

Per direction from the Deputy Chief of Staff of the Army, G-4/Logistics (DCS G-4), this plan, if approved, will establish timelines, identify operational/tactical tasks, assign responsibilities, and establish metrics to measure progress in meeting the energy security goals prescribed in the AESIS.

This plan, upon approval, will be executed under the direction and governance of the Army SEE, who will assign offices of primary responsibility to manage execution and report progress in concert with other energy-related objectives, using the Army Strategic Management System (SMS), ensuring the synchronization of efforts aimed at meeting the Army's overall energy security vision, mission, and goals.

There is no single "silver bullet" solution to energy security in the operational environment. Rather, the solution requires a set of coordinated actions, including: adoption of an Army culture that values energy, implementation of comprehensive energy management tools, advances in military platform technologies, and exploitation of scientific advances in alternative fuels and renewable energy sources.

Way Ahead

Current Department of the Army (DA) and Department of Defense (DOD) energy initiatives and evolving operational requirements demand an operationally focused forum to advise the SEE and Army leadership. There remains no single office designated to focus solely on operational energy issues. This leads to a lack of synchronization among agencies focusing on operational energy needs across the Army.

The Army should consider establishing an Operational Energy Office of Primary Responsibility to serve as the focal point and advocate for operational energy initiatives. This office would synchronize efforts across the Army while coordinating with the other services to ensure Joint interoperability. The office would be accountable to coordinate operational energy capabilities and performance, providing the Army a means to balance investments in technologies, human capital, and performance improvement. The Office director would develop a comprehensive campaign plan and establish business processes and practices consistent with current and emerging Army and the DOD concepts and doctrine. The position must also have decision and tasking authority and an adequate staff and resources to address issues confronting the Army.

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1.0 INTRODUCTION

Purpose

The purpose of this document is to provide the Army with a Tactical Fuel and Energy Implementation Plan (TFEIP) that will: synchronize the Army's efforts, both within the Army and across the Joint community; reduce redundant efforts; and leverage previous and on-going efforts. This plan provides a guideline for fuel and energy efforts in the tactical environment from now through 2028. Per direction from the Deputy Chief of Staff of the Army, G-4/Logistics (DCS G-4), this plan, if approved, will establish timelines, identify tasks, assign responsibilities, and establish metrics to measure progress in meeting the energy security goals prescribed in the Army Energy Security Implementation Strategy (AESIS).

Background

To facilitate development of a cohesive Army-wide approach to energy security, the Secretary of the Army commissioned the Army Energy Security Task Force (AESTF) in April 2008. The AESTF assessed the Army energy security posture and developed recommendations for reducing Army energy consumption, increasing energy efficiency across platforms and facilities, promoting the use of new sources of alternative energy, establishing benchmarks for reducing the Army's energy footprint and providing guidance for the creation of a culture of energy awareness across the Army based on the principles of Leadership, Partnership and Ownership.[1]

As a result of the AESTF recommendations, the Deputy Assistant Secretary of the Army (DASA) for Energy & Partnerships (DASA (E&P)) and the Army Senior Energy Council (SEC) were established. The DASA (E&P), serving as the Army's Senior Energy Executive (SEE), monitors and reports the Army's progress toward stated energy goals. DASA (E&P) produced the AESIS to implement the AESTF guidance and communicate the Army's energy security vision, mission, and goals.[2]

The AESIS establishes five strategic energy security goals (ESG) for the Army:[3]

- ESG 1. Reduced Energy Consumption
- ESG 2. Increased Energy Efficiency Across Platforms and Facilities
- ESG 3. Increased Use of Renewable/Alternative Energy
- ESG 4. Assured Access to Sufficient Energy Supply
- ESG 5. Reduced Adverse Impacts on the Environment

The current list of Energy Security Objectives (ESOs) in support of the AESIS ESGs does not adequately address operational energy requirements (See Annex A to Appendix A). The TFEIP corrects this shortfall.

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[1] *Army Energy Security Implementation Strategy*, Army Senior Energy Council, 13 January 2009, 1.
[2] Ibid.
[3] Ibid., 3-4.

This plan is focused on the tactical environment, defined as maneuver brigade combat team (BCT) and below. The study team developed the objectives and tasks within the conceptual framework outlined by the 2010 Joint Operating Environment (JOE) and The Army Capstone Concept (ACC) Operational Adaptability - Operating under Conditions of Uncertainty and Complexity in an Era of Persistent Conflict 2016-2028.

The sponsor of this study, the DCS G-4, directed that this effort deliver a product that is of value to the Army and aggressively supports achievement of Army energy security goals. Specific guidance included:

- Focus on three primary goals: a) reduce energy consumption; b) reduce dependence on petroleum through use of renewable and alternative energy sources; and c) reduce tactical logistics support requirements for fuel and energy.
- Provide detailed metrics for all implementation activities.
- Provide prioritized recommendations for implementation of proposed solutions.
- Provide preliminary business case analyses for 2-4 high-payoff solutions identified by the Government.
- Provide analysis and recommendations to inform the Single Fuel on the Battlefield policy issue per DCS G-4's SEC Office of Primary Responsibility (OPR) responsibilities.
- Provide analysis and recommendations to inform the development of automated fuel accountability systems.
- Provide analysis and recommendations to inform development of requirements documentation and key performance parameters (KPP).

Critical to the process of developing this document was the establishment of the TFEIP Working Group (TFEIP WG). The TFEIP WG, with representation from a broad spectrum of Army and Joint power and energy partners and stakeholders, collaborated in an open forum to develop the TFEIP, examining ongoing and planned efforts in fuels and energy, including alternative fuels and renewable energy sources, to develop a plan that supports the DCS G4 guidance.

Assumptions

The study team made the following assumptions to support the development of the tactical energy security objectives and implementation activities:

1. Senior Army leadership will lead and actively support culture change efforts.
2. Senior Army leadership will support the implementation of changes across the Doctrine, Organization, Training, Materiel, Leadership, Personnel and Facilities (DOTMLPF)

domains that will result in demand reduction and the reduction in tactical force logistics support requirements for fuel and energy.

3. Current legacy equipment, platforms, systems and fleets will not be replaced until the end of their planned life-cycles unless replacement is determined to be cost effective or driven by operational necessity.

4. Technological improvements in energy conservation efficiencies will allow for the achievement of desired consumption reduction goals while maintaining or increasing existing capability levels.

5. Existing platforms and systems can be modified/re-tooled/retrofitted if necessary to achieve desired efficiencies.

6. The Army will have the ability to establish a baseline tactical force fuel usage for Fiscal Year (FY) 2012 (FY12).

7. Technologies will be mature enough to allow for an enterprise sharing of data and to provide necessary solutions for an automated energy management system.

8. The U.S. Army will remain dependent on petroleum-based fuels for tactical operations from now until the 2028 timeframe encompassed by this study.

AESIS Synchronization

Once approved and adopted by the SEC, the Office of the DASA (E&P) (ODASA (E&P)) will integrate the objectives, tasks and metrics developed in this TFEIP with the objectives and metrics that ODASA (E&P) previously developed that are focused on the tactical and operational environments under the governance structure of the AESIS, ensuring the synchronization of efforts aimed at meeting the Army's overall energy security vision, mission, and goals.

In accordance with the AESIS and Army SEE's June 2010 directive (Subject: Assignment of Offices of Primary Responsibility for Army Energy Security Implementation Strategy Metrics), identified Offices of Primary Responsibility (OPRs) will execute and implement the plan. Responsibilities of the OPRs (from Headquarters Department of the Army (HQDA), Army Commands (ACOMs), Army Service Component Commands (ASCCs), Direct Reporting Units (DRUs) and Field Operating Agencies (FOAs)) include:

- Develop, design, fund and execute implementation plans that include activities to achieve goals and objectives.

- Develop proposed policies, directives or instructions to make metrics actionable.

- Identify and coordinate needed support from Offices of Coordinating Responsibility (OCR).
- Use the Planning, Programming, Budgeting & Execution System (PPBES) as the primary method for addressing energy requirements, ensuring that activities supporting accomplishment of the ESGs are a priority within their Program Objective Memorandum (POM) and requirements building process.
- Perform the necessary data management and oversight to ensure the AESIS metric information is correctly documented in the Army Strategic Management System (SMS) so that progress is accurately reported to the SEC and SEE.

In developing the proposed solutions in this plan, the study team implicitly incorporated the fundamental principle prescribed in the AESIS, namely: "that the improvements achieved shall not lead to reductions in operational capability or the ability of the Army to carry out its primary missions. The solutions being considered to achieve these energy goals will effectively maintain and enhance operational capabilities, achieve long term cost savings, and strengthen the ability of the Army to fulfill its missions."[4]

[4] *Army Energy Security Implementation Strategy*, Army Senior Energy Council, 13 January 2009, 3.

2.0 ENERGY SECURITY GOALS AND OBJECTIVES

The AESIS directs that action-oriented energy security objectives (ESO) be established to guide development and coordination of implementation activities, programs and investments by the Army.[5] The ESOs will provide the focus necessary for the Army to comply with key directives and to achieve the ESGs.[6] The following is a discussion of the ESOs that support strategic and tactical ESGs which are oriented on the operational use of energy.

ESG 1 - Reduce energy consumption.

The Army's dependence on bulk fuel creates tactical logistics support requirements that have the potential to slow operations and make deployed forces more vulnerable to enemy attack. Reducing tactical fuel consumption, combined with improvements in energy efficiency and increasing the use of renewable energy sources, will reduce bulk fuel convoy operations, exposing fewer Soldiers to hostile fire who would otherwise be executing those convoys.[7]

The first step toward long-term petroleum independence is reducing consumption. There are many possible methods to achieve this goal, but all must work together synergistically to achieve the desired effect. The methods most conducive to rapid implementation are through: reduced energy demand; energy conservation that results from energy awareness at the individual and command level coupled with more energy efficient processes; and increased platform efficiency.

To achieve this goal, a shift in Army culture regarding energy is required and the Army must institutionalize the concept of fuel and energy savings across all levels. Army leaders at all levels must be trained to recognize or create opportunities to conserve energy and be prepared to exploit them.[8] As stated in the AESIS, "The foundation of the Army Energy Vision is Ownership. Taking ownership leads to accountability and a cultural change for Army personnel. Ownership comes from knowledge, training, and operational awareness of the importance of energy to all aspects of the Army mission. Ownership and cultural awareness begins immediately upon a Soldier's induction into the Army and a Civilian's first day of employment. Successfully addressing the Army's energy security needs will be highly dependent on the Army's culture of ownership."[9] To support the development of that culture of ownership, the study team developed the following ESO:

- ESO 1.1: An Army culture that values energy efficiency and conservation at the platform and system level.

[5] *Army Energy Security Implementation Strategy*, Army Senior Energy Council, 13 January 2009, 9.
[6] Ibid.
[7] *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, 17.
[8] *Tactical Fuel and Energy Strategy for the Future Modular Force (Final Draft)*, U.S. Army Combined Arms Support Command, 18 May 2009, 36.
[9] *Army Energy Security Implementation Strategy*, Army Senior Energy Council, 13 January 2009, 3.

Successfully reducing energy consumption also requires an understanding of the energy consumption profile (how and where energy is being consumed). The Defense Science Board (DSB) in their 2008 study noted "effectively managing fuel demand requires an in-depth understanding of the activities that are creating the demand".[10] Currently, detailed fuel supply data is available (what is delivered to the theater or the battlefield), but detailed consumption data for actual military operations (how the fuel is actually used, e.g., combat and tactical vehicles, generators) is not available. Army leaders at all levels will continue to not have the ability to make informed decisions regarding energy demand and fuel usage without required data and the tools to gather that data. To address this shortfall, the study team developed the following ESO:

- ESO 1.2: By 2015, integration of effective fuel and energy data collection and analysis tools that allow leadership to assess, manage, and evaluate tactical force energy demand.

ESG 2 – Increased energy efficiency across platforms and facilities.

Increased platform efficiency is a critical component of the synergy required to achieve long-term petroleum independence. While operational capabilities cannot be compromised, in an energy-constrained environment, efficiency becomes its own effect, enabling the sustained application of other desired military effects. To support the achievement of ESG 2, the study team developed the following ESO:

- ESO 2.1: By 2028, improved energy efficiencies across tactical platforms and camps that result in an overall 20% reduction in tactical force fuel use from FY12 consumption.

ESG 3 – Increased use of renewable/alternative energy.

The goal of reducing dependency on petroleum through the increased use of renewable and alternative energy sources can only be met through the synergy achieved by the integration of alternative and renewable energy solutions with the successful implementation of other initiatives targeting the reduction of energy and fuel consumption. Alternative fuel and renewable energy solutions should be developed to reduce petroleum-based fuel requirements to the maximum degree possible. While these solutions can lessen the amount of petroleum-based fuels required, they will not be able to replace petroleum-based fuels in the near- and mid- terms.[11] According to a 2006 report from the JASONs, "DOD is not a sufficiently large customer to drive the domestic market for demand and consumption of fossil fuel alternatives, or to drive fuel and transportation technology developments, in general. Barring externalities, e.g., subsidies, governmental and

[10] *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, 15.
[11] *Tactical Fuel and Energy Strategy for the Future Modular Force (Final Draft)*, U.S. Army Combined Arms Support Command, 18 May 2009, 6.

departmental directives, etc., non-fossil-derived fuels are not likely to play a significant role in the next 25 years."[12]

While DOD may not be a market driver for fossil fuel alternatives, the JASON report also makes the case that there are several compelling reasons for the Army to minimize petroleum-based fuel use, including: fuel use imposes large logistical burdens, operational constraints and liabilities, and vulnerabilities (otherwise capable offensive forces can be countered by attacking more-vulnerable logistical supply chains – the "rear" is now vulnerable, especially the fuel supply line); fuel use is characterized by large multipliers and co-factors: at the simplest level, it takes fuel to deliver fuel; uncertainties about an unpredictable future make it advisable to decrease DOD fuel use to minimize exposure and vulnerability to potential unforeseen disruptions in world and domestic supply.[13]

In order to support the achievement of ESG 3 in the tactical force environment, the study team developed the following two ESOs:

- ESO 3.1: By 2028, at least 25% of energy used for tactical level power generation is derived from alternative and renewable sources.

- ESO 3.2: By 2028, 50% of the fuel requirement in the training base for the tactical mobility fleet (surface and air) is met by alternative fuel blends.

DCS G-4 Goal – Reduce tactical force logistics support requirements for fuel and energy.

The DCS G-4's guidance for the TFIEP included the goal of reducing tactical logistics support requirements for fuel and energy. The essence of meeting this goal is to reduce the resources required (personnel and materiel) to receive, store, and distribute fuel. Energy and fuel saving initiatives that reduce overall consumption will, in effect, reduce logistics support requirements. Alternative and renewable energy sources also have the potential to reduce the quantity of fuel required, although this may result in a shift or transference of fuel and energy support requirements from petroleum-based fuels to alternative fuels.

The study team developed the following ESO in support of this additional tactical fuel and energy goal:

- ESO 4.1: By 2028, achieve a 10% reduction in the tactical force logistics support required for fuel and energy from 2010 baseline.

Leadership at all levels will be critical to the accomplishment of these ESOs. Leaders need to continually provide the context as to why energy management is important to not only the Army, but to national security and the global economy, and enable Soldiers to integrate energy management into their standard operating procedures. Leaders must communicate, provide guidance, and be accountable for increasing energy efficiency throughout their organizations.

[12] *Reducing DOD Fossil-Fuel Dependence*, Report JSR-06-135, JASON, the Mitre Corporation, 12 September 2006, iv.
[13] Ibid.

Leaders must emphasize the importance of energy efficiency and where possible change current practices and habits to use less energy when conducting training or ground operations. In order to ensure sustained efforts around energy management, leaders must be responsible for not only providing the framework for energy management, but also for making sure that energy management practices are actually implemented at all levels.

3.0 IMPLEMENTATION ACTIVITIES

The AESIS is focused on implementation.[14] As outlined in the AESIS, implementation activities (IA) represent the actions taken by OPRs to support established ESOs in the ultimate achievement of the ESGs.[15] This chapter focuses on the ESOs and the intended outcomes that represent the desired end state to be achieved in the execution of the proposed IAs. The complete list of IAs with OPRs, metrics and targets are listed in Appendix A. Additionally, ODASA (E&P) has developed ESOs and Metrics that support the attainment of the ESGs in the tactical environment and are listed in Annex A to Appendix A.

Many of the proposed objectives and implementing activities identified in this plan will require execution in accordance with the Joint Capabilities Integration and Development System (JCIDS) process, to include the development of requirements documents, for which Training and Doctrine Command (TRADOC) is responsible.

3.1 ESO 1.1: An Army culture that values energy efficiency and conservation at the platform and system level.

The Army must be committed to creating a culture where all Soldiers and civilians understand the importance of power and energy management and are encouraged to execute energy-saving strategies when possible. The following components are required for successful cultural change: 1) Dedication and Commitment of Senior Leadership; 2) Strategic Communication; 3) Education & Training.

Senior leader support of the cultural change is absolutely essential. Speaking of the DOD's current energy challenge as a strategic opportunity, Amory B. Lovins, the Chairman and Chief Scientist at the Rocky Mountain Institute, states "The need to change entrenched habits in force planning and operational requirements makes big new capabilities both vital and hard. Driving them deeply into doctrine, strategy, organizational structures, cultures, training, reward systems, and behaviors requires strong, consistent, persistent senior leadership."[16]

Senior leader support of culture change must extend beyond verbal support into behavioral support for the change. Senior leaders must lead the change by being role models for the change. Commanders will need to champion energy efficiency practices throughout their organizations. Changing the culture of the Army to one that prioritizes efficient energy utilization will require leadership from current and future leaders who have been trained and indoctrinated into a culture of energy awareness and conservation. Leaders at all levels are accountable for executing energy management practices.

Effective communications that keep Soldiers informed about the cultural change process ensures commitment and success. Telling Soldiers what is expected of them is critical for

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[14] *Army Energy Security Implementation Strategy*, Army Senior Energy Council, 13 January 2009, 8.
[15] Ibid., 10.
[16] Amory B. Lovins, "DOD's Energy Challenge as Strategic Opportunity," *Joint Forces Quarterly* 57 (2d Quarter 2010), 36.

effective cultural change. Soldiers must clearly understand what is expected of them, and must know how to implement the new behaviors, once they have been defined.

Education is essential in establishing energy awareness across the Army. Establishing the context as to why energy needs to be a consideration of daily operations will be critical to sustaining energy management strategies. The Army will rely on all Soldiers to recognize and create opportunities to conserve energy and be prepared to execute tasks as needed in their daily activities to achieve the Army's overarching energy goals. Fuel efficiency and energy conservation must be incorporated into the Army's standard operating procedures. Energy awareness must be integrated into the Army's operations from policy guidance to procedures implemented at the squad level. Energy must be part of the operational awareness equation, whereby Soldiers across the range of operations ensure energy is a consideration and a commodity that cannot be wasted. As energy education and awareness grows and permeates throughout the force, it can be anticipated that many initiatives for energy efficiency will come from the Soldiers engaged in daily operations at the platform and system level. Therefore, communication channels need to flow not only from senior leadership down, but from the lowest levels up.

In order to achieve the Army's energy goals, leaders must habitually implement power and energy efficiency practices into daily operations. Leaders and planners must integrate power and energy management into operational planning and execution with care taken to balance the facilitation of effective behaviors and meaningful decisions without distracting from accomplishment of the mission.

The following intended outcomes, representing the desired end state to be achieved in the execution of proposed IAs, are focused on changing the Army culture to one that understands the importance of power and energy management as a combat multiplier and values energy efficiency and conservation at the platform and system level:

- By FY11 develop a strategic communication program that provides guidance that can be seamlessly integrated across mission areas and clearly communicates the Army's priorities, goals and objectives, and performance expectations, thus setting the energy management framework for all Soldiers and ensuring cohesion of effort.

- By FY13 field a power and energy awareness training program targeted to all levels of Soldiers that will serve to establish the context as to why energy needs to be a consideration in daily operations; ensure program uniformity; and ensure cohesion of effort across the Army. The program should address Army operational energy priorities and objectives; the importance of energy in the conduct of operations; how individuals can impact energy use; how individuals can make a difference in the Army's energy consumption.

- By FY13, field in officer and non-commissioned officer professional development institutions, a formal power and energy management education program that educates Army leaders about power and energy management, leader influence on

outcomes, and to enable leader facilitation of effective behaviors and meaningful decision making.

3.2 ESO 1.2: By 2015, integration of effective fuel and energy data collection and analysis tools that allow leadership to assess, manage, and evaluate tactical force energy demand.

As discussed earlier, leadership is the critical component to a successful campaign to reduce energy demand and consumption. In order for leaders to effectively lead the change efforts, they must have the right tools to inform their power and energy management and leadership decisions. The DCS G-4, in a 2010 white paper developed collaboratively with the Army Capabilities Integration Center (ARCIC) and the Research, Development and Engineering Command (RDECOM), has identified as the number one power and energy grand challenge the capability to "give Soldiers and leaders a means to manage – measure, monitor and control energy status, usage and system performance: prioritize and redistribute resources. This challenge includes…integration of power and energy management into operational planning and execution…"[17]

In their 2008 study, the DSB noted "effectively managing fuel demand requires an in-depth understanding of the activities that are creating the demand. Unfortunately, data in energy usage are unevenly collected across the Department, making it difficult to form a comprehensive picture."[18] The study goes on to note that for operational systems, the Defense Logistics Agency-Energy (DLA-E) operates an accounting system for the purpose of tracking purchases, but data showing where it is used, for what purpose, and by which end-items are inconsistent. The Air Force keeps excellent records of aircraft fuelings by tail number, quantity, date, and location. Data on use by ground systems are not collected.[19]

The Government Accounting Office (GAO) concluded in February 2009, that "By placing a higher priority on fuel reduction at forward-deployed locations and developing a comprehensive and coordinated approach to managing fuel demand, one that includes specific guidelines, …visibility, and accountability, DOD would be more likely to achieve its goals of reducing its reliance on petroleum-based fuel, the vulnerabilities associated with transporting large amounts of fuel to forward-deployed locations, and operational costs."[20] Additionally, TRADOC has identified among several technology-oriented Warfighter Outcomes for expeditionary base camps the need to "establish power management processes and tools to determine, monitor and adjust load demand…"[21]

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[17] *Power and Energy Strategy White Paper*, Army Capabilities Integration Center – Research, Development and Engineering Command – Deputy Chief of Staff, G4, US Army, 1 April 2010, 1.
[18] *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, 15.
[19] Ibid.
[20] *Defense Management: DOD Needs to Increase Attention on Fuel Demand Management at Forward-Deployed Locations*, U.S. Government Accountability Office Report to the Subcommittee on Readiness, Committee on Armed Services, House of Representatives, February 2009, 34.
[21] *Power and Energy Strategy White Paper*, Army Capabilities Integration Center – Research, Development and Engineering Command – Deputy Chief of Staff, G4, US Army, 1 April 2010, 9.

To address the challenges identified by the DCS G-4, the shortcomings identified by the DSB and TRADOC, and implement the recommendations of the GAO at the tactical level, the Army needs to develop and field an automated energy management capability within both the Battle Command and Army Enterprise systems. The solution should:

- Generate, collect and analyze energy demand and consumption for tactical vehicles, equipment and tactical level base camps.

- Integrate fuel and energy data/information needs into effective automated tools that allow leaders to assess and manage energy demand and use.

- Integrate fuel and energy data/information into an effective automated decision support tool that communicates fuel and energy requirements for a proposed operation and the impacts (risks) of sub-optimal quantities on success.

The Fuels Manager Defense (FMD) module of Defense Logistics Agency's (DLA) Business Systems Modernization-Energy (BSM-E) is an example of a potential component of a larger automated energy management capability, providing a web-based standard fuels accounting tool. FMD provides the ability to maintain asset visibility of petroleum quantities across the full spectrum of operations with the following capabilities:

- Track consumption to the individual vehicle/weapons system.

- Automated source data collection and integration capability from automated tank gauges, temperature compensating meters, and automated and manual data input devices.

- Provide a mechanism for specialized customer support through customized terminal interfaces which allow user-generated database queries on accounts.

- Use telecommunications assets that promote real-time or near real-time data processing.

See Appendix C for further discussion of FMD.

Leaaders must have the right tools to inform their power and energy management and leadership decisions. Army leaders at the tactical level need an automated tool to monitor fuel status and consumption patterns/rates of tactical equipment (at a minimum defined as combat vehicles and aircraft, tactical wheeled vehicles, tactical generator sets). Base camp energy consumption also requires automated, semi-automated and/or manual data entry and analysis tools for effective base camp energy management. Information on fuel and energy demand and consumption must be aggregated, transmitted and available to higher headquarters (up to the ASCC and HQDA) for assessment and managerial oversight. The proposed solution should use the Army's Battle Command system for data transmission, which should then be centrally archived for analytical purposes by Army Enterprise systems.

The following intended outcomes are focused on providing a system that collects energy demand and fuel consumption for tactical equipment and/or base camps with sufficient fidelity to enable effective management of energy at all levels:

- By FY14 field a Battle Command integrated solution that permits automated fuel and energy management and planning support up to ASCC level.

- By FY15 expand this capability to the Army Enterprise enabling tracking, analysis and high level management of tactical energy, in near real time.

3.3 ESO 2.1: By 2028, improved energy efficiencies across tactical platforms and camps that result in an overall 20% reduction in tactical force fuel use from FY12 consumption.

In FY09, the Army consumed over 620 million gallons of fuel for Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF).[22] Reducing that amount by 20%, or 124 million gallons, would have the effect of reducing the number of fuel truck loads by over 37,500, reducing required fuel convoys by over 2,500, and most importantly, reducing Soldier exposure in convoys by reducing the number of Soldier trips by over 307,000.[23] The value of a 20% reduction in fuel consumption in terms of Soldier risk reduction, logistics support requirements and cost avoidance is clearly evident.

The following table, extracted from a 2008 DSB study, illustrates that the Army's peacetime and wartime fuel consumption patterns differ considerably. During peacetime, fuel consumption by Army aircraft makes up almost 50% of its total. But during wartime, generators become the largest single fuel consumers on the battlefield.[24]

	Army Peacetime Consumption		**Army Wartime Consumption**	
Equipment Category	Gallons Consumed (millions)	Percent of Total Consumption	Gallons Consumed (millions)	Percent of Total Consumption
Combat Vehicles	30	10.31%	162	15.43%
Combat Aircraft	140	48.11%	307	29.23%
Tactical Vehicles	44	15.12%	173	16.48%
Generators	26	8.93%	357	34.00%
Non-Tactical	51	17.53%	51	4.86%
Total	**291**	**100%**	**1050**	**100%**

Table 1 – Army Fuel Consumption in Peacetime and Wartime (million gallons per year)[25]

[22] Army Petroleum Center, email message to the authors, 19 January 2010.
[23] Derived from a briefing by Mr. Paul P. Bollinger, Jr., DASA (E&P), titled "Army Energy Strategy – The Way Ahead," presented to the Soldier Family Readiness Board of Directors, 30 September 2008.
[24] *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, 44.
[25] Ibid.

This table serves to identify the areas where fuel is being consumed and in what proportion, in order to illustrate the relative impacts of fuel consumption reduction efforts. This chart clearly shows that efforts to reduce the fuel consumption in generators will have the most impact, followed by fuel consumption reduction efforts for aviation platforms, tactical vehicles, and combat vehicles. The cumulative effect of a holistic approach to fuel consumption reduction in each area will lead to successful achievement of the Army's fuel demand reduction goals.

The following sections, divided into base camps, aircraft and vehicles, discuss platform and equipment efficiency gains associated with technology improvements and the suggested activities necessary for implementing these solutions.

Base Camps

According to the 2008 DSB study identified earlier, 34% of the fuel consumed in wartime is consumed by power generation equipment.[26] Of the power being generated, 50-90% is used for environmental control units (ECU).[27] As this is the area of highest fuel consumption on the battlefield, it follows that reducing the fuel required for power generation will have the most significant effect on overall Army tactical fuel consumption. Increasing the efficiency of generators will significantly reduce the amount of fuel needed on the battlefield. Coupled with the capability to efficiently supply and use generated power, will result in an even greater reduction in fuel demand. Solutions available in the near-term include:

- Assessing the power needs of tactical units and matching power generation capability to the unit's power needs (right-sizing generator sets).[28] Right sizing is based on getting it right *before* unit deployment. Right sizing involves identifying actual power draws of equipment (not just nameplate data); actual and anticipated duty cycles, possible distribution issues (which loads could be on which generator), and determining the generator sizing that minimizes required power while still providing for reasonable/expected maximum loading.[29]

- Fielding the Command Post (CP) Central Power system which will reduce the number of power generators required to meet the power demands of a command post by introducing a power distribution system that will allow for more efficiently matching generated power to demand.[30]

[26] *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, 44.
[27] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 29 March 2010.
[28] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 28 February 2010.
[29] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 21 July 2010.
[30] *Tactical Electric Power (TEP) – Emerging Technologies and Initiatives that Influence Organization Power Needs White Paper*, U.S. Army Combined Arms Support Command, January 2009, 7.

- Fielding the Advanced Medium Mobile Power Source (AMMPS) family of generators, which has been shown in testing to be 20% more fuel efficient than the Tactical Quiet Generators (TQG).[31]

- Fielding the Improved Environmental Control Unit (IECU), which has been shown to be up to 25% more efficient than current ECUs.[32]

Fielding these systems will result in immediate fuel demand reduction over current consumption levels.

Future solutions for an integrated power generation and management capability that will be available for integration in the mid-term include micro-grids and intelligent power management systems which have already been proven effective in the commercial sector. A micro-grid is an integrated energy system consisting of interconnected loads and distributed energy resources that can operate in parallel with a grid or in an intentional island mode.[33] An "intelligent" micro-grid is characterized by: integrated distributed energy sources, capable of providing sufficient and continuous energy to mission critical loads; independent controls allowing islanding and reconnection with minimal disruption; flexible configuration and operation of the power delivery system.[34]

Hybrid Intelligent Power (HI-Power) is an intelligent micro-grid system currently under development by the Project Manager-Mobile Electric Power (PM-MEP). As envisioned, the HI-Power architecture will provide a modular "plug and play" power grid and intelligent control to command posts. Unique for a tactical power generation and distribution system, HI-Power will accept any type of available power source: military or commercial generator sets, vehicle exported power, energy storage, local utility, hybrid power generation systems and renewable sources. The system will use intelligent power management to dispatch and synchronize the multiple power inputs, allow load balancing, generator cycling, and more efficient use of all available resources, thus minimizing the use of fossil-fuel powered generator sets. The system will also use energy storage for managing load transients, thus increasing the overall energy conversion efficiency with reduced fuel use. Fielding HI-Power has the potential to reduce fuel consumption in command posts by power generation systems by 25% or more.[35]

The following intended outcomes are focused on reducing overall fuel consumption by developing and fielding power generation and environmental control equipment and ancillary systems that are more efficient than systems currently in use:

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[31] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 28 February 2010.

[32] Paul Richard, Deputy Project Manager, Mobile Electric Power, DOD Mobile Electric Power Systems Command Brief, March 2009.

[33] Clark Boriack, Senior Technical Manager, Concurrent Technologies Corporation, in a briefing titled "Software Modeling and Validation of a Microgrid," delivered to the Alternative Energy NOW Conference, Orlando, FL, 9 February 2010.

[34] Ibid.

[35] Michael Padden, Project Manager, Mobile Electric Power, "Tactical Electric Power Overview" briefing to the Army Science Board, 3 March 2010.

- By FY16 field the Command Post Central Power distribution system to Brigade Combat Team command posts which will more efficiently match generated power to demand.

- By FY22 field the IECU.

- By FY24 field the HI-Power tactical intelligent micro-grid system.

- By FY28 field the AMMPS family of generators.

Aircraft

According to the 2008 DSB study, 29% of the fuel consumed in wartime is consumed by combat aircraft.[36] This makes combat aircraft the next area in which reduced fuel consumption will have an impact on overall Army fuel consumption.

The system focus areas readily available for improving the efficiency of these platforms include engine efficiency and transmission improvements. The following intended outcomes are focused on the aircraft systems that are readily available for efficiency improvements:

- By FY23 field a replacement engine on all Blackhawk and Apache aircraft that achieves a fuel consumption reduction of 25% over the current T-700 engine.[37]

- By FY26 field a replacement engine on all Chinook aircraft that achieves a fuel consumption reduction of 35% over the current T-55 engine.[38]

- By FY24 field a replacement transmission on all Blackhawk and Apache aircraft that achieves a 40% increase in horsepower to weight ratio over the current transmissions.[39]

- By FY28 field a replacement transmission on all Chinook aircraft that achieves a 55% increase in horsepower to weight ratio over the current transmissions.[40]

[36] *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, 44.
[37] Kevin Alexandre, Office of the Program Executive Officer-Aviation, email message to the authors, 11 February 2010.
[38] Ibid.
[39] Ibid.
[40] Ibid.

Vehicles

The 2008 DSB study determined that 32% of the fuel consumed in wartime is consumed by vehicles (combat vehicles – 15%; tactical vehicles- 17%).[41] Solutions that target reducing energy consumption must be carefully balanced with the requirement to maintain the desired operational characteristics of the platform, to include Soldier safety, survivability, range, power, maneuverability, endurance and combat effectiveness.

In order to determine optimal solutions for this objective, a holistic approach is required for the platform being considered. For instance, fuel efficiencies gained from a new, fuel efficient engine coupled with an improved transmission and drive train can be easily nullified by an increased overall weight if optimization efforts targeting weight reduction are not synchronized with the propulsion efforts. For example, the Stryker Modernization (S-Mod) Capability Development Document (CDD) will establish a KPP that requires all ten Stryker variants have a cruising range of 330 miles, a 15% improvement. Since the S-Mod vehicles will be heavier and require the C-9 engine which has more horsepower than the current 3126 and C-7 engines, both externally rear mounted fuel tanks have been enlarged to carry an extra 5 gallons each. This will increase the Stryker's total fuel capacity from 53 to 63 gallons. Thus, the S-Mod vehicles are expected to meet the requirement; however, they are not expected to have greater fuel economy than the current Strykers.[42]

Improving the fuel efficiency in legacy vehicle systems and developing and fielding improved efficiency replacement vehicle systems for those that are reaching the end of scheduled life-cycles will result in reducing the overall fuel consumption in vehicles.

The following intended outcomes are focused on reducing overall fuel consumption in vehicles by improving the fuel efficiency in legacy systems and developing and fielding improved efficiency replacement systems for those that are reaching the end of scheduled life-cycles:

- By FY20, field the Joint Light Tactical Vehicle (JLTV) that will achieve 60 ton-miles per gallon.[43]
- By FY22, field the Ground Combat Vehicle (GCV) that is at least a 10% improvement in moving fuel consumption than the Bradley Fighting Vehicle (BFV) of equal weight.[44]
- By FY25, the Family of Medium Tactical Vehicles (FMTV) is at least 15% more fuel efficient than current models.

[41] *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, 44.
[42] Terry Dean, Office of the Program Manager, Stryker Brigade Combat Team, email to the authors, 17 May 2010.
[43] *Power and Energy Strategy White Paper*, Army Capabilities Integration Center – Research, Development and Engineering Command – Deputy Chief of Staff, G4, US Army, 1 April 2010, 13.
[44] Ibid., 14.

- By FY25, the Heavy Expanded Mobility Tactical Truck (HEMTT) is at least 15% more fuel efficient than current models.

- By FY26, the Abrams tank can perform one day (threshold) to two days (objective) of combat operations using only on-board fuel as specified in KPP 5.[45]

3.4 ESO 3.1: By 2028, at least 25% of energy used for tactical level power generation is derived from alternative and/or renewable sources.

This objective, which focuses on the reduction of the dependence on petroleum fuels and the requirement to haul fuels, addresses power generation requirements associated with tactical operations in a combat outpost (COP). COPs have a short lifecycle and employ tents for shelter along with select components of the Force Provider system. Infrastructure is likely to comprise portable generators, temporary wiring, water storage, crude toilets and showers.[46] The power demand for this level of operation does not generally exceed 60 kilowatts (kW), and may be much less for smaller, more austere bases. Solutions to support meeting this objective need to be rapidly deployable, highly mobile, modular, simple and robust; setup and maintenance must be within the capabilities of the average Solider.

The use of alternative and renewable energy sources for power generation may lead to a reduction in liquid fuels that will need to be transported to the tactical level. Alternative and renewable energy technologies, such as photovoltaic solar panels, wind turbines, and micro-hydro turbines, currently exist in several forms that can supplement power generation at the tactical level. The benefit of each technology will vary based on the environment a particular technology operates within: wind profiles for wind turbines and available sunlight for solar systems for instance.

Testing and evaluation of several technologies are in progress by various organizations and Services of the military. Examples include:

- Natick Soldier Research Development and Engineering Center (NSRDEC) is evaluating a "Solar Tent" that incorporates flexible solar panels providing 1 to 2 kilowatts of power which can be utilized for a variety of purposes ranging from lighting to ventilation to power for field communication radios, global positioning system devices, and recharging satellite phones and laptop computers.[47]

- Communications-Electronics Research Development and Engineering Center (CERDEC) is evaluating a portable flexible solar panel (<100 watts) that can provide power for requirements such as powering small electronic devices and battery re-charging.[48]

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[45] *Power and Energy Strategy White Paper*, Army Capabilities Integration Center – Research, Development and Engineering Command – Deputy Chief of Staff, G4, US Army, 1 April 2010, 13.
[46] Ibid., 8-9.
[47] CERDEC Briefing, "Reducing Fuel Logistics for Power Generation & Environmental Control", 27 January 2010.
[48] Ibid.

- The Marine Corps' Deployable Renewable Energy Alternative Module (DREAM) effort is a trailer mounted solar-generator-battery hybrid trailer-mounted system; optimized for a 96 hour mission and approximately a 3 kW mission load.[49]

- PM-MEP is developing a generator auto-start capability that would enable the use of renewable and alternative power generation sources in conjunction with existing Army generators.[50]

- NSRDEC is evaluating waste-to-energy (WTE) conversion efforts which converts waste product to synthetic fuel for use in generator sets.[51]

- CERDEC and the Army Materiel Systems Analysis Activity (AMSAA) are currently working on the creation of an analytical tool that can optimize power generation at various locations. The insertion of renewable energy sources such as solar, wind, and hydro into the battlefield will require tools that will enable the analytical community to determine the best mix of power generation technologies for given environmental conditions.[52]

The Army must continue the testing and evaluations to advance and field technologies to enhance the understanding of real-world military applications and the stressors each technology must endure, and use that information in spiral development cycles.

Not all alternative and renewable energy solutions readily lend themselves to application in the whole of the tactical environment. Wind, geothermal, hydroelectric, and WTE solutions are available for consideration as alternative and renewable options, however application of these technologies should only be considered for installations that are more semi-permanent or permanent in nature, for the reasons stated below:

- Small wind systems have potential to be utilized as a form of supplemental power in a systems based solution in the tactical environment. Larger, ground-based wind systems typically are too big and heavy for rapid movement and should only be considered for permanent installations. Additionally, possible issues of wind turbine interference with early-warning or counter-fire radars (such as false returns or masking) will need to be mitigated before wind can be fully integrated.

- The excavation requirement to install a geothermal system does not lend itself to the highly mobile nature of company level operations.

- The need for a flowing water source for hydroelectric power generation renders its use to very limited scenarios.

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[49] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 28 February 2010.
[50] Ibid.
[51] Don Pickard, NSRDEC, email message to the authors, 23 February 2010.
[52] Peter Dymond, Army Materiel Systems Analysis Activity, email message to the authors, 3 September 2010.

- Although the waste stream generated in a company sized tactical COP (roughly 1000 pounds/day (8 pounds/Soldier[53])), could produce enough fuel (<50 gallons/day at 22 pounds/gallon[54]) to operate a 60kW generator for the majority of a day (average 3.3 gallons per hour[55]) thus reducing the amount of fuel that needs to be transported, the current size of a WTE system (1-2 20 foot ISO containers), precludes their deployment in a tactical COP. WTE systems do, however, possess a desirable secondary effect of eliminating burn pits or the need to transport waste to disposal sites, which coupled with the energy created, warrants their continued S&T investment by the military.[56]

The following sections discuss the potential alternative and renewable energy sources best suited for the tactical environment and the suggested activities necessary for implementing these potential solutions.

Solar

Beyond efficiency improvements in existing power generators, solar power clearly shows potential for reducing fuel consumption, especially for small users like isolated combat outposts. However, solar power is currently still very expensive by comparison and can be space intensive. Also, it is difficult to envision 10s to 100s of kWs of energy being provided by solar for tactical applications. Solar is very cyclical by definition, and therefore power generation will still require backup liquid fuel consuming systems and/or energy storage systems.

In the short term, solar photovoltaic (PV) technology demonstrations and evaluations worldwide are on-going to get real-world data and feedback from the Soldier for use in spiral development and technology marketing/awareness efforts. These demonstrations and evaluations will evolve into mid-term efforts ranging from PV applications development to technology efficiency increases working at the cell and module levels. Longer term activities will ultimately include PV base technology improvements and development of additional emerging PV technologies.

These intended outcomes are focused on integrating solar power into power generation capabilities, thus reducing dependence on petroleum-based fuels:

- By FY15, field solar technologies that provide up to 3kW of tactical level power.

- By FY24, field solar technologies that provide up to 10kW of tactical level power.

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[53] *Tactical Electric Power (TEP) – Emerging Technologies and Initiatives that Influence Organization Power Needs White Paper*, U.S. Army Combined Arms Support Command, January 2009, 25.
[54] Ibid., 26.
[55] John Carroll, RDECOM Power and Energy Technology Focus Team, email message to the authors, 3 September 2010.
[56] Scott Haase, National Renewable Energy Laboratory, briefing titled "Status of Several Biomass and WTE Assessments for DOD", presented to the Alternative Energy NOW Conference, Orlando FL, 10 February 2010.

- By FY28, field solar technologies that provide at least 15kW of tactical level power.

Alternative Fuels

The U.S. Army will remain dependent on petroleum-based fuels for tactical operations from now until the 2028 timeframe encompassed by this study. As long as petroleum-based fuels are less expensive than other fuel or energy sources, this nation will continue to focus on the use of petroleum-based fuels. As alternative fuels become economically competitive with petroleum based fuel, then a shift will occur.[57] As the shift to alternative fuels occurs, liquid fuel consuming platforms must have the capability to operate on those fuels. The Army needs to have liquid fuel consuming tactical power generation platforms that are capable of using those alternative fuels that have been approved for use.

The U.S. Air Force (USAF), in conjunction with DLA-E, is leading the effort to identify alternative fuels that are a "drop-in" replacement for jet propellant 8 (JP-8), meaning that the alternative fuel mimics the characteristics of JP-8.[58] As alternative fuels are identified, the Army is testing the fuels, including laboratory evaluations, component evaluations, system evaluation and demonstrations, in order to qualify them for use in Army equipment and platforms.[59]

ODASA (E&P) has developed ESOs with metrics that address actions required to facilitate the use of alternative fuels in tactical and combat vehicles, ground equipment, aircraft and aviation systems. (See Annex A to Appendix A.)

3.5 ESO 3.2: By 2028, 50% of the fuel requirement in the training base for the tactical mobility fleet (surface and air) is met by alternative fuel blends.

As previously discussed, DLA-E and USAF are taking the lead on identifying non-petroleum based fuels that serve as "drop-in" replacements for JP-8, in order to meet the USAF stated goal of using alternative fuel blends to meet 50% of its domestic jet fuel requirements in their flight operations by 2016[60]. The Army's focus is on platform performance using the identified alternative fuels.[61] To this end, RDECOM is currently evaluating alternative fuels for use in Army engines and platforms. ODASA (E&P) developed an ESO that calls for alternative fuels to be evaluated for use in 100% of ground vehicle engines by 2014, and aircraft engines by 2016. Upon completion of those evaluations, the use of approved alternative fuels can be integrated into daily training base operations as the fuels become available.

[57] *Tactical Fuel and Energy Strategy for the Future Modular Force (Final Draft)*, U.S. Army Combined Arms Support Command, 18 May 2009, 33.
[58] Kevin Geiss, ODASA (E&P), Comments to the Army Science Board, Washington, D.C., 4 March 2010.
[59] Tank and Automotive Research Development and Engineering Center (TARDEC) briefing to the 4th Annual Alternative Energy NOW Conference, Orlando, FL, 9 February 2010.
[60] *Air Force Aviation Operations Energy Plan 2010*, U.S. Air Force Deputy Chief of Staff, Operations, Plans and Requirements (AF/A3/5), 6.
[61] Kevin Geiss, ODASA (E&P), Briefing to the Army Science Board, Washington, D.C., 4 March 2010.

The worldwide availability of alternative fuels will undoubtedly increase as they continue to develop and become more mainstream and commonplace. While the Army's use of alternative fuels will also increase worldwide as fuels become available, commanders conducting combat operations need to be unencumbered by a requirement to use alternative fuels and must continue to use the fuel that is most readily available, be it petroleum based or non-petroleum based. However, the opportunity exists in training environments and in routine garrison operations to maximize the integration of alternative fuels to meet requirements. Therefore this objective focuses on exploiting that opportunity. Using FY09 consumption figures, a 50% usage of alternative fuel blends, similar to the USAF goal, would have resulted in replacing 66 million gallons of petroleum based fuels with alternative fuels.[62]

The following intended outcomes, coupled with existing ODASA (E&P) ESOs and metrics that address actions required to facilitate the use of alternative fuels, are focused on integrating the use of alternative fuels in vehicle and aircraft engines in the training base:

- By FY18, at least 15% of the fuel requirement in the training base for the tactical mobility fleet is met by alternative fuel blends.
- By FY23, at least 30% of the fuel requirement in the training base for the tactical mobility fleet is met by alternative fuel blends.
- By FY28, at least 50% of the fuel requirement in the training base for the tactical mobility fleet is met by alternative fuel blends.

3.6 ESO 4.1: By 2028, achieve a 10% reduction in the tactical force logistics support required for fuel and energy from 2010 baseline.

Energy and fuel saving initiatives that reduce overall fuel consumption could, in effect, reduce logistics support requirements. Implementation of the actions outlined in the previous sections will have the desired cumulative effect of reducing overall fuel consumption that could allow for the reduction in tactical force logistics support requirements, not only in military support, but also in contractor support that is required to receive, store, and deliver fuel on the battlefield.

The intended outcomes that follow, coupled with contributing existing SEC Objectives and Metrics, are focused on reducing the tactical force logistics support required for fuel and energy:

- By FY25, at least 5% reduction in the tactical force logistics support required for fuel and energy from FY10 baseline.
- By FY28, at least 10% reduction in the tactical force logistics support required for fuel and energy from FY10 baseline.

[62] Army Petroleum Center, email message to the authors, 19 January 2010.

4.0 RECOMMENDATIONS

The study team recommends that the Army execute each of the implementation activities identified in this plan to achieve the synergy needed in the tactical environment to support meeting the ESGs identified in the AESIS. Emphasis on the following initiatives by senior Army leadership will have the most immediate impact on fuel reduction and set the conditions for sustained efforts in operational and tactical fuel and energy management in support of achieving the Army's Energy Security vision and goals.

Recommendation 1: Adopt the TFEIP objectives, implementation activities, timelines and metrics into the Army Energy Security Implementation Strategy and Plan

Critical to the success of this endeavor is the integration of these proposed ESOs and associated implementation activities into the governance structure of the SEC, thus ensuring the cohesion of these energy activities with the total Army effort. The study team recommends that these ESOs and associated IAs, metrics and targets be integrated into the Army's Energy Security Implementation Strategy and Plan.

Recommendation 2: Establish an Operational Energy Office of Primary Responsibility

Current Department of the Army (DA) and Department of Defense (DOD) energy initiatives and frequently changing operational requirements necessitate a forum that links the operational, capability development, science and technology and acquisition communities to advise and make recommendations to the SEE and the Army leadership. There remains no single office/point of contact designated to focus solely on operational energy issues. While many agencies/offices are working operational energy needs within their respective areas, there is limited synchronization across the Army absent such a designated office.

The study team recommends that the Army establish an Operational Energy Office of Primary Responsibility to serve as the focal point and advocate for energy initiatives which support tactical operations. This office would be charged to synchronize efforts across the Army while coordinating with the other services to ensure all efforts reflect the Joint environment. The office would be accountable for mobility energy matters, develop a comprehensive strategic tactical energy plan, and improve the Army's business processes and practices consistent with current and emerging Army and the DOD concepts and doctrine. The position must also have decision and tasking authority and an adequate staff and resources to address issues confronting the Army. Additionally, the office will establish policy for tactical equipment, as well as oversee the various ongoing projects across the width and breadth of the Army.

As efforts continue in the science and technology arena to advance platform fuel efficiencies and alternative and renewable energy possibilities, thus enabling the execution of the proposed implementation activities, there are several priority areas on which the Army should focus efforts now to begin to realize reductions in fuel consumption.

Recommendation 3: Institute culture change

Changing the Army culture is the bedrock foundation on which the accomplishment of these goals rest. As stated in the AESIS, "The foundation of the Army Energy Vision is Ownership. Taking ownership leads to accountability and a culture change for Army personnel. Ownership comes from knowledge, training, and operational awareness of the importance of energy to all aspects of the Army mission. Ownership and culture awareness begins immediately upon a Soldier's induction into the Army and a Civilian's first day of employment. Successfully addressing the Army's energy security needs will be highly dependent on the Army's culture of ownership."[63] The study team recommends that efforts in this area commence immediately.

Recommendation 4: Develop, produce, and field data measurement/capture capability

The study team stresses in this plan that leadership is the critical component to a successful campaign to reduce energy demand and consumption. In order for leaders to effectively lead the change efforts, the study team recommends that the Army field a data capture and measurement capability to provide leaders the right tools to inform their power and energy management and leadership decisions.

Recommendation 5: Field AMMPS Family of Generators

According to the 2008 DSB study, 34% of the fuel consumed in wartime is consumed by power generation equipment.[64] The capability to efficiently supply and use generated power will significantly reduce the amount of fuel needed on the battlefield. Fielding the AMMPS family of generators will lead to fuel consumption reductions of up to 20% over currently fielded generators. The study team recommends the Army field the AMMPS family of generators.

Recommendation 6: Field IECU

As mentioned above, 34% of the fuel consumed in wartime is consumed by power generation equipment. Of the power being generated, 50-90% is used for environmental control units.[65] Fielding the IECU will lead to power consumption reductions of up to 25% over currently fielded environmental control units. The study team recommends the Army field the IECU.

Recommendation 7: Develop and field Hybrid Intelligent Power (HI-Power) tactical micro-grid capability

HI-Power has the potential to reduce fuel consumption by power generation systems by 25% or more, resulting in a nearly 10% reduction in overall tactical force fuel use. The study team recommends the Army field HI-Power.

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[63] *Army Energy Security Implementation Strategy*, Army Senior Energy Council, 13 January 2009, 3.
[64] *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, 44.
[65] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 29 March 2010.

5.0 CONCLUSION

The purpose of this document is to provide the Army a guideline for fuel and energy efforts in the tactical environment from now through the 2016-2028 future force timeframe. The Army's dependence on bulk fuel creates tactical logistics support requirements that have proven to slow operations and make forces supplying that bulk fuel more vulnerable to enemy attack. Reducing tactical fuel consumption and increasing the use of renewable and alternative energy sources will reduce bulk fuel convoy operations thereby exposing fewer Soldiers to hostile fire who would otherwise be executing those convoys.

In developing the proposed solutions in this plan, the study team implicitly incorporated the fundamental principle prescribed in the AESIS, namely: that the improvements achieved shall not lead to reductions in operational capability or the ability of the Army to carry out its primary missions...will effectively maintain and enhance operational capabilities, achieve long term cost savings, and strengthen the ability of the Army to fulfill its missions.

Leadership at all levels will be critical to the accomplishment of the objectives identified in this document. Leaders will need to continually provide the context as to why energy management is important to not only the Army, but to national security and the global economy, and enable Soldiers to integrate energy management into their standard operating procedures. Leaders must communicate, provide guidance, and be accountable for increasing energy efficiency throughout their organizations. Leaders must emphasize the importance of energy efficiency and where possible change current practices and habits to use less energy when conducting training or ground operations. In order to ensure sustained efforts around energy management, leaders must be responsible for not only providing the framework for energy management, but also for making sure that energy management practices are actually implemented at all levels.

There is no single "silver bullet" solution in the tactical environment to meeting the ESGs for the Army as outlined in the AESIS. The solution lies in the cumulative, synergistic effects that the Army will realize by executing each of the implementation activities in pursuit of the accomplishment of the objectives stated herein: an Army culture that values energy coupled with appropriate power and energy management tools, application of platform technological advances, and exploitation of scientific advances in alternative fuels and renewable energy.

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APPENDIX A - IMPLEMENTATION ACTIVITIES WITH METRICS

Implementation Activity	OPR	OCRs	Metric	Target	Start	End
ESO 1.1: An Army culture that values energy efficiency and conservation at the platform and system level.						
IA 1.1.1: Develop and promulgate senior leadership strategic communications that: outline Army operational power and energy management priorities; provide performance-oriented guidance; provide effective feedback.	ASA (I&E)		Completed/Not Completed	Completed	01 Oct 2010	Enduring
IA 1.1.2: Implement the Army level power and energy efficiency/conservation awareness training program for all personnel in the unit/organization.	HQDA G3	FORSCOM TRADOC AMC ASCCs DRUs	% of personnel trained	100%	01 Oct 2012	Enduring
IA 1.1.2.1: Develop an Army level power and energy efficiency/conservation awareness training program.	TRADOC		% Completed	100%	01 Oct 2011	30 Sep 2012
IA 1.1.3: Develop and integrate power and energy management curricula for officer and non-commissioned officer professional development schools.	TRADOC		% Integration into target courses	100%	01 Oct 2011	30 Sep 2012
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Implementation Activity	OPR	OCRs	Metric	Target	Start	End
ESO 1.2: By 2015, integration of effective fuel and energy data collection and analysis tools that allow leadership to assess, manage, and evaluate tactical force fuel demand						
IA 1.2.1: Develop and field a Battle Command integrated solution for automated fuel and energy management and operational planning support up to ASCC level. Field and sustain Battle Command supported system as required.	ASA (ALT)		% Completed	100%	01 Oct 2012	30 Sep 2013
IA 1.2.2: Develop enterprise system requirements and architecture, analysis tools, data storage and management solutions for the Enterprise component of the energy management system.	AMC	ASA(ALT)	% Completed	33% 66% 100%	01 Oct 2011 01 Oct 2012 01 Oct 2013	30 Sep 2012 30 Sep 2013 30 Sep 2014
Continued Next Page						

Implementation Activity	OPR	OCRs	Metric	Target	Start	End
ESO 2.1: By 2028, improved energy efficiencies across tactical platforms and camps that result in an overall 20% reduction in tactical force fuel use from Fiscal Year (FY) 2012 (FY12) consumption.						
IA 2.1.1: Complete fielding of the Command Post Central Power distribution system for BCT command posts.	ASA (ALT)		% of systems fielded	75% 100%	01 Oct 2011 01 Oct 2012	31 Sep 2012 31 Sep 2015
IA 2.1.2: Field the AMMPS family of generators.	ASA (ALT)		% of AMMPS generators fielded	50% 75% 100%	01 Oct 2012 01 Oct 2020 01 Oct 2024	30 Sep 2020 31 Sep 2024 30 Sep 2027
IA 2.1.3: Field the IECU.	ASA (ALT)		% of IECUs fielded	50% 75% 100%	01 Dec 2010 01 Oct 2016 01 Oct 2019	30 Sep 2016 31 Sep 2019 30 Sep 2021
IA 2.1.4: Field the HI-Power tactical intelligent micro-grid.	ASA (ALT)		% of systems fielded	50% 75% 100%	01 Oct 2015 01 Oct 2019 01 Oct 2021	31 Sep 2019 30 Sep 2021 30 Sep 2023
IA 2.1.5: Field a replacement engine on all Blackhawk and Apache aircraft that replaces the T-700 engine.	ASA (ALT)		% of aircraft with new engines	50% 75% 100%	01 Oct 2018 01 Oct 2020 01 Oct 2021	30 Sep 2020 30 Sep 2021 30 Sep 2022
IA 2.1.6: Field a replacement engine on all Chinook aircraft that replaces the T-55 engine.	ASA (ALT)		% of aircraft with new engines	50% 75% 100%	01 Oct 2021 01 Oct 2023 01 Oct 2024	30 Sep 2023 30 Sep 2024 30 Sep 2025
IA 2.1.7: Field the replacement transmission for the Blackhawk and Apache aircraft that meets identified requirements.	ASA (ALT)		% of aircraft with new transmissions	50% 75% 100%	01 Oct 2018 01 Oct 2021 01 Oct 2022	30 Sep 2021 30 Sep 2022 30 Sep 2023
IA 2.1.8: Field the replacement transmission for Chinook aircraft that meets identified requirements.	ASA (ALT)		% of aircraft with new transmissions	50% 75% 100%	01 Oct 2024 01 Oct 2025 01 Oct 2026	30 Sep 2025 30 Sep 2026 30 Sep 2027
IA 2.1.9: Field the Abrams tank upgrades and improvements that allow the Abrams to perform two days of operations with on-board fuel as specified in KPP 5.	ASA (ALT)		% of Abrams Tanks with upgrades and improvements	50% 75% 100%	01 Oct 2022 01 Oct 2023 01 Oct 2024	30 Sep 2023 30 Sep 2024 30 Sep 2025
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Implementation Activity	OPR	OCRs	Metric	Target	Start	End
IA 2.1.10: Field the Ground Combat Vehicle (GCV) that is at least a 10% improvement in moving fuel consumption than the Bradley Fighting Vehicle (BFV) of equal weight.	ASA (ALT)		% of GCVs fielded	50% 75% 100%	01 Oct 2018 01 Oct 2019 01 Oct 2020	30 Sep 2019 30 Sep 2020 30 Sep 2021
IA 2.1.11: Field the Joint Light Tactical Vehicle (JLTV) that will achieve 60 ton-miles per gallon.	ASA (ALT)		% of JLTV fielded	50% 75% 100%	01 Oct 2016 01 Oct 2017 01 Oct 2018	30 Sep 2017 30 Sep 2018 30 Sep 2019
IA 2.1.12: Field FMTV upgrades and improvements that result in FMTV that is at least 15% more fuel efficient than the current FMTV.	ASA (ALT)		% of FMTVs with upgrades and improvements	50% 75% 100%	01 Oct 2021 01 Oct 2022 01 Oct 2023	30 Sep 2022 30 Sep 2023 30 Sep 2024
IA 2.1.13: Field HEMTT upgrades and improvements that result in HEMTT that is at least 15% more fuel efficient than the current HEMTT.	ASA (ALT)		% of HEMTTs with upgrades and improvements	50% 75% 100%	01 Oct 2021 01 Oct 2022 01 Oct 2023	30 Sep 2022 30 Sep 2023 30 Sep 2024
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Implementation Activity	OPR	OCRs	Metric	Target	Start	End
ESO 3.1: By 2028, at least 25% of energy used for tactical level power generation is derived from alternative and renewable sources.						
IA 3.1.1: Field a solar power solution for mobile power generator applications with the capability of providing up to 3 KW of power from solar sources.	ASA (ALT)		% fielded	100%	01 Oct 2013	30 Sep 2014
IA 3.1.2: Field a solar power solution for Field Services, Field Feeding, Shelter Systems and Force Provider equipment with the capability of providing up to 3 kW of power from solar sources.	ASA (ALT)		% of Organizational equipment and Service provided equipment fielded	100%	01 Oct 2013	30 Sep 2014
IA 3.1.3: Field a solar power solution for mobile power generator applications with the capability of providing up to 10 kW of power from solar sources.	ASA (ALT)		% fielded	50% 75% 100%	01 Oct 2020 01 Oct 2021 01 Oct 2022	30 Sep 2021 30 Sep 2022 30 Sep 2023
IA 3.1.4: Field a solar power solution for Field Services, Field Feeding, Shelter Systems and Force Provider equipment applications with the capability of providing up to 10 kW of power from solar sources.	ASA (ALT)		% of Organizational equipment and Service provided equipment fielded	50% 75% 100%	01 Oct 2020 01 Oct 2021 01 Oct 2022	30 Sep 2021 30 Sep 2022 30 Sep 2023
IA 3.1.5: Field a solar power solution for mobile power generator applications with the capability of providing at least 15 kW of power from solar sources.	ASA (ALT)		% fielded	50% 75% 100%	01 Oct 2025 01 Oct 2026 01 Oct 2027	31 Sep 2026 30 Sep 2027 30 Sep 2028
IA 3.1.6: Field a solar power solution for Field Services, Field Feeding, Shelter Systems and Force Provider equipment applications with the capability of providing at least 15 kW of power from solar sources.	ASA (ALT)		% of Organizational equipment and Service provided equipment fielded	50% 75% 100%	01 Oct 2025 01 Oct 2026 01 Oct 2027	31 Sep 2026 30 Sep 2027 30 Sep 2028
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Implementation Activity	OPR	OCRs	Metric	Target	Start	End
ESO 3.2: By 2028, 50% of the fuel requirement in the training base for the tactical mobility fleet (surface and air) is met by alternative fuel blends.						
IA 3.2.1: Integrate the use of alternative fuel blends in combat and tactical vehicles and aircraft to satisfy training and garrison fuel requirements.	AMC	FORSCOM TRADOC AMC ASCCs DRUs	% of training and garrison fuel requirement met by alternative fuel blends	15% 30% 50%	1 Oct 2016 1 Oct 2017 1 Oct 2022	30 Sep 2017 30 Sep 2022 30 Sep 2027
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Implementation Activity	**OPR**	**OCRs**	**Metric**	**Target**	**Start**	**End**
ESO 4.1: By 2028, achieve a 10% reduction in the tactical force logistics support required for fuel and energy from 2010 baseline.						
IA 4.1.1: Based on G-3 priorities, resource approved tactical force logistics support structure requirements for fuel and energy that result in at least 5% reduction in the tactical force logistics support required for fuel and energy from FY10 baseline.	DCS, G-8		% Completed	50% 100%	01 Oct 2022 01 Oct 2023	30 Sep 2023 30 Sep 2024
IA 4.1.1.1: Based on fuel and energy efficiencies gained and associated consumption reductions realized by FY20, conduct analysis to determine the tactical force logistics support structure requirement for fuel and energy, with a goal of at least 5% reduction from FY10 force structure levels.	TRADOC		% Completed	100%	01 Oct 2020	30 Sep 2021
IA 4.1.1.2: Approve proposed force structure and prioritize resourcing requirements.	DCS, G-3		% Completed	100%	01 Oct 2021	30 Sep 2022
IA 4.1.2: Based on G-3 priorities, resource tactical force logistics support structure requirements for fuel and energy that result in at least 10% reduction in the tactical force logistics support required for fuel and energy from FY10 baseline.	DCS, G-8		% Completed	50% 100%	01 Oct 2026 01 Oct 2027	30 Sep 2027 30 Sep 2028
IA 4.1.2.1: Based on fuel and energy efficiencies gained and associated consumption reductions realized by FY24, conduct analysis to determine the tactical force logistics support structure requirement for fuel and energy, with a goal of at least 10% reduction from FY10 force structure levels.	TRADOC		% Completed	100%	01 Oct 2024	30 Sep 2025
IA 4.1.2.2: Approve proposed force structure and prioritize resourcing requirements.	DCS, G-3		% Completed	100%	01 Oct 2025	30 Sep 2026

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ANNEX A – ODASA (E&P) TACTICAL OBJECTIVES AND METRICS, TO APPENDIX A - IMPLEMENTING ACTIVITIES WITH METRICS

		ENERGY SECURITY GOALS(ESGs), OBJECTIVES & METRICS	OFFICES OF PRIMARY RESPONSIBILITY (OPRs)
ESG 1. Reduced Energy Consumption			
Objective 1.1 Institutionalize energy/fuels savings/conservation procedures across all levels.			
	1.1b	% of commands and installations with complete energy management plans	ACSIM, FORSCOM, TRADOC
	1.1c	% of key positions (Commanders and Directors) with energy management accountability in support forms and job performance objectives throughout the chain of command	G-1
	1.1e	Implementation of fuel and energy consumption as a consideration in tactical planning or mission execution (Complete/ Not complete)	G-3
Objective 1.2 Provide full-time, trained, and certified energy managers to lead the energy program on each installation and within all commands.			
	1.2a	% of installations and commands with staffing standards and establish energy positions	ACSIM, ACOMs, ASCCs, DRUs
	1.2c	# of energy managers on staff # of energy managers trained # of energy managers certified	ACSIM, ACOMs, ASCCs, DRUs
Objective 1.6 Improve tactical fuel inventory management by mitigating losses from poor handling practices or theft through enhanced management practices and command oversight.			
	1.6a	% of out-of tolerance tactical accounts (AFG & IZ)	ARCENT
Objective 1.7 Establish an automated fuel accountability system to validate baseline fuel consumption and provide consistency and accuracy to enterprise level fuel asset visibility.			
	1.7a	Develop requirements for an automated fuel management system (Complete/ Not complete)	TRADOC
	1.7b	Field automation package to meet Army automated fuel management system requirements (Complete/ Not complete)	AMC
	1.7c	Establish an enterprise level baseline for reporting of consumption data (Complete/ Not complete)	AMC
Objective 1.8 Adopt policies to ensure insulation is required when constructing temporary structures.			
	1.8a	Update Army technical design manuals Series: TM 5-301-1 thru 4 to include insulation requirements for temporary structures (Complete/ Not complete)	OCE
	1.8b	Develop policy (coordinate with COCOMS) to ensure % of all key temporary structures in Iraq/Afghanistan are insulated at R14 value (via coordination with ARCENT) (Complete/ Not complete)	ASA(I&E)
ESG 2. Increased Energy Efficiency Across Platforms and Facilities			
Objective 2.4 Establish a comprehensive mid to long-term plan for DOTMLPF changes and introduction of alternative and energy efficient tactical platforms.			
	2.4a	Develop the strategy and implementation plans to identify tactical fuel and energy requirements for the future modular force (Complete/ Not complete)	TRADOC
Objective 2.5 Minimize the Types of Fuel on the Battlefield.			
	2.5a	Identify, review, and update policies, as necessary, relating to the use of the predominant military fuel available in theater (Complete/Not complete)	G-4
Objective 2.6 Increase energy efficiency of current tactical equipment/platforms.			
	2.6a	Develop strategy and implementation plans from current effort to identify tactical fuel and energy requirements for the modular force (Complete/ Not complete)	TRADOC

ESG 3. Increased Use of Renewable/Alternative Energy			
Objective 3.3 Transition from fossil fuel based tactical mobility/power generation to alternative and renewable energy/sources.			
	3.3a	% of Army tactical ground equipment systems for which alternative and renewable fuels and synthetic fuel blend evaluations are completed	ASA(ALT), AMC
	3.3b	% of Army engine and aviation systems for which alternative and renewable fuels and synthetic fuel blend evaluations are completed	ASA(ALT), AMC
	3.3c	Assess renewable feedstocks and fuels or second-generation biofuel technologies that provide products suitable for military use that will withstand all temperatures and operating conditions. (Complete/ Not complete)	AMC
	3.3d	% of Army AOR power generation requirements met by renewable/alternative sources	ASA(I&E)
ESG 4. Assured Access to Sufficient Energy Supply			
Objective 4.4 Command participation in annual evaluation of DLA-E inventory management plan (Ensure considerations for increased storage requirements, where applicable, to mitigate fossil fuel supply interruptions as global demand increases and supply decreases.)			
	4.4a	% participation by ACOM, ASCC and DRU with fuel logistics responsibilities	AMC

APPENDIX B - ANALYSIS AND RECOMMENDATIONS TO INFORM THE SINGLE FUEL ON THE BATTLEFIELD POLICY

The DCS G-4 provided the following guidance for this study regarding the single fuel on the battlefield policy: Provide analysis and recommendations to inform the single fuel on the battlefield policy issue, per G-4's SEC OPR responsibilities (SEC metric 2.5).

SEC Metric 2.5a reads "Identify, review, and update policies, as necessary, relating to the use of the predominant military fuel available in theater."

Department of Defense Directive (DODD) 4140.25 establishes the predominant fuel on the battlefield policy for DOD. DODD 4140.25 states:

> "The Combatant Commanders shall develop plans to minimize the types of fuels required in joint operations...Primary fuel support for land-based air and ground forces in all theaters (overseas and in the Continental United States) shall be accomplished using a single kerosene-based fuel, in order of precedence: JP-8, commercial jet fuel (with additive package), or commercial jet fuel (without additives), as approved by the Combatant Commander. Fuel support for ground forces may also be accomplished using commercially available diesel fuel when supplying jet fuel is not practicable or cost effective…The type of fuel designated for the battlefield shall be specified by the Combatant Commander depending on fuel availability and equipment to be used within the theater."[1]

DODD 4140.25 also states that it is the responsibility of the Secretaries of the Military Departments to "Prescribe additional policies, procedures, research, development, acquisition, planning, programming, and budgeting guidance to implement fuel standardization policy..."[2]

Additionally, it states that the Secretary of the Army will:

- Provide wartime planning and management of overland petroleum distribution support, including inland waterways, to U.S. land-based forces of all DOD Components.
- Fund and maintain tactical storage and distribution systems to supplement fixed facilities.
- Provide the necessary force structure to operate and install tactical petroleum storage and distribution systems, including pipelines.[3]

[1] Department of Defense Directive 4140.25, April 12, 2004, Subject: DOD Management Policy for Energy Commodities and Related Services, paragraph 4.2.
[2] Ibid., paragraph 5.5.2.
[3] Ibid., paragraph 5.6.

The single fuel on the battlefield policy was developed in part to simplify the logistics required to provide fuel to the forces. The functions of fuel storage, transportation, and distribution can be tailored for maximum efficiency with a single battlefield fuel. Maintaining multiple storage and distribution equipment and networks contributes to the logistics burden for the Army, particularly in the tactical environment, where the option to use contractors to conduct receipt, storage, and issue operations is not practicable, and is not synchronized with the DCS G-4 goal of reducing the tactical force logistics support requirements for fuel and energy.

Per the 2008 DSB Study, 66% of the wartime jet fuel consumed by the Army was consumed in platforms other than combat aircraft.[4] In FY09, that amounted to approximately 317 million gallons, at a product-only non-fully burdened cost of approximately $647 million.[5] It is this amount of fuel that could be potentially replaced by commercially available diesel fuel, if proven to be more cost effective than jet fuel in accordance with DOD policy.

Using the FY09 figures, substituting the 317 million gallons of jet fuel with diesel fuel would have resulted in an 11% savings ($70 million) in the product-only, non-fully burdened cost of the fuel ($577 million for diesel versus $647 million for jet).[6] This cost savings would have to be compared to the costs, in both manpower and equipment, associated with maintaining separate storage and distribution networks for jet and diesel fuels.

Care need be taken when considering the cost effectiveness of potential fuel savings associated with updating existing platforms with more fuel efficient engines that burn other than jet fuel. For example, the Abrams tank accounts for 61% of the fuel consumed by combat vehicles.[7] Using the FY09 consumption figures, that would equate to 44 million gallons consumed by Abrams tanks in the Central Command (CENTCOM) Area of Responsibility (AOR). Installing a modern diesel engine in the Abrams tank that may have the potential for 10% fuel savings would result in 4 million gallons saved, which is less than 1% of the 610 million gallons of fuel the Army consumed in the CENTCOM AOR.[8] Maintaining a separate storage and distribution system for 66% of the Army's total fuel requirement in order to reduce total fuel consumption by less than 1% clearly identifies the need for rigorous analysis in order to realistically determine the overall cost effectiveness of such an option.

Recommendation:

DOD policy, as outlined in DODD 4140.25, supports the DCS G-4 goal of reducing the tactical logistics support requirements for fuel and energy. Recommend that the Army's review of policies relating to the use of the predominant military fuel available in theater include a rigorous analysis that realistically compares potential cost savings to the added logistics burden of maintaining multiple storage and distribution networks as well as tactical and operational consequences of any changes.

[4] *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, 44.
[5] Army Petroleum Center, email message to the authors, 19 January 2010.
[6] Ibid.
[7] *Tactical Fuel and Energy Strategy for the Future Modular Force (Final Draft)*, U.S. Army Combined Arms Support Command, 18 May 2009, 13.
[8] Army Petroleum Center, email message to the authors, 19 January 2010.

APPENDIX C - ANALYSIS AND RECOMMENDATIONS TO INFORM DEVELOPMENT OF TACTICAL AUTOMATED ACCOUNTING SYSTEMS

The DCS G4 provided the following guidance for this study regarding tactical automated accounting systems: Provide analysis and recommendations to inform the development of automated accountability systems. Must clearly show how such systems will help to achieve the goal of reducing the Army's consumption of fuel.

Bottom line, automated accountability systems will not directly reduce consumption of fuel. The enhanced visibility gained through automating fuel accountability will create an environment where oversight of fuel usage will be possible in a way that it is not today. Automated accountability systems will: help to reduce the amount of money spent by the Army on fuel by improving accountability; aid in reduction of theft, pilferage and fraud; and ensure that the Army is properly reimbursed from its customers through enhanced and improved secondary billing capabilities.

In FY09, the Army purchased 882 million gallons ($2B) for worldwide operations including OIF and OEF. The Army currently does not have an automated capability to account for and control an inventory of this magnitude, to include the ability to accurately identify and bill its customers, leading to the Army unnecessarily absorbing operational costs that should have be borne by other organizations. Additionally, this lack of appropriate asset visibility limits the capability to determine trends, process failures, detect theft, or pinpointing needed system efficiencies.

The Petroleum and Water Functional Needs Assessment conducted by the Sustainment Center of Excellence (SCoE) and approved by TRADOC identifies as a medium risk capability gap that petroleum distribution managers at all levels (to include Petroleum Groups, Theater and Divisional Sustainment Brigades, and Brigade Support Battalions) lack the ability to maintain asset visibility of petroleum quantities across the full spectrum of operations, which limits the ability to execute a collaborative command and control (C2) process while monitoring the logistics support plan execution in order to identify and react rapidly to deviations.

From the tactical level forward, there is no real time or near real time mechanism to track bulk petroleum. Current asset visibility for fuel on the battlefield requires manual data collection and reporting. Commanders make allocation decisions based on the Bulk Petroleum Contingency Report (REPOL), a daily report that in Operation Iraqi Freedom (OIF) is 12-36 hours dated by the time it gets to higher planners and decision-makers. This lack of real-time information does not allow commanders or planners to accurately determine on-hand totals or resupply requirements. The end result is a resupply effort which often overestimates the true requirement, thereby requiring more fuel than really necessary to meet stockage objectives. Compounded across multiple storage sites, the results are additional storage requirements and distribution assets for increased levels of fuel. In order to effectively conduct distribution-based sustainment over extended distances, commanders have a critical requirement for timely and accurate inventory data. An ability to accurately measure inventory and track shipments will provide needed asset visibility to support the force. In addition to contributing to sustained operational tempo and extending operational reach, the number and frequency of fuel convoys/sorties could also be reduced, with a corresponding reduction in the vulnerability of these assets and the number of soldiers pulled from other duties to protect them. Without the capabilities of a secure

and pervasive petroleum C2 support infrastructure, the speed, precision, accuracy, visibility, and centralized management of petroleum operations will not keep pace with the expeditionary environment of the future force.

Theft of fuel in the area of operations (AO) has been a major problem. Over a twelve month period, from May 07 to Apr 08, 10.5 million gallons of fuel, valued at over $29 million, went unaccounted for from the Victory Base Complex in Iraq. There have been eighteen on-going or closed CID investigations involving fuel theft in AO. The use of an automated accountability system coupled with proper command oversight could have reduced theft by up to 90%.[1]

Under Title 10, United States Code, the Army is required to provide bulk petroleum regardless of the scale of the contingency to the Joint Force and is required to provide support to U.S. government agencies, non-governmental organizations, international organizations, and host-nation agencies. While providing this support, the Army requires the capability to simultaneously plan for potential future operations while maintaining the initiative during on-going operations.

The development and fielding of an automated computer based system will: provide near real time total asset visibility; enable all commanders and logistic managers to observe and take appropriate action on requirements forecasting and the application of effective theater Class III management for the requisition, sourcing, distribution, receipt, issue, storage, inventory of fuels; and enable interoperability with available C2 and battle command systems for in-transit visibility (ITV). Without automation capability, distribution managers will be limited in their ability to perform precision tactical resupply and provide rapid and accurate petroleum sustainment integrated with combat operations in the expeditionary environment of the future force.

The major components required for an automated accountability system include:

- Tactical automated tank gauging capability that eliminates the need for manual gauging of storage tanks and bags, reducing the likelihood of human errors

- Temperature compensating meters that provide accurate quantities of product issued and received

- Automated web-based standard fuels accounting tool with source data collection and database storage capability

DLA's Business Systems Modernization-Energy (BSM-E) is an Automated Information System (AIS) designed to support DLA-E and the Military Services in performing their responsibilities in fuel management and distribution. BSM-E is multi-functional AIS that provide point-of-sale data collection, inventory control, finance and accounting, procurement, and facilities management information. BSM-E will support the business functions of acquisition and contract management, supply management, facilities management, financial management, and decision support. The Fuels Manager Defense (FMD) module of BSM-E provides an existing solution for the Army's capability gap for an automated web-based standard fuels accounting tool. The FMD

[1] Dave Corbin, Deputy Director, Army Petroleum Center, email message to the authors, 21 April 2010.

is an automation tool that significantly enhances internal controls and the capability for command oversight of tactical fuel operations. FMD provides the ability to maintain asset visibility of petroleum quantities across the full spectrum of operations, enabling the ability to execute a collaborative C2 process while monitoring the logistics support plan execution in order to identify and react rapidly to deviations. FMD provides the Army with an automated web-based standard fuels accounting tool with the following capabilities:

- Track consumption to the individual vehicle/weapons system.
- Provide a Common Operating Picture between Services.
- Secondary billing capability when used in conjunction with BSM-E.
- Automated source data collection and integration capability from automated tank gauges, temperature compensating meters, and automated and manual data input devices.
- Increase fuel accountability by supporting fuel transactions at all Defense Fuel Support Points (DFSP) and retail point-of-sale data collection sites.
- Decrease data processing time through the use of modern automation techniques which are compatible with the Electronic Data Interchange (EDI) standards. Integrate new fuel technology systems (automatic tank gauges, automatic leak detection, and reporting systems) into BSM-E.
- Provide a mechanism for specialized customer support through customized terminal interfaces which allow user-generated database queries on accounts.
- Use telecommunications assets that promote real-time or near real-time data processing.

Use of FMD along with establishment of an Army Enterprise, coupled with automated tank gauging and temperature compensated metering will address the Army's tactical needs.

Recommendations:

- Field Tactical Fuels Manager Defense (FMD) automated petroleum accountability and management system as the Army Standard Management Information System (STAMIS) for Class III (B).
- Develop and field an automated tank gauging capability for tactical fuel storage bags and tanks.
- Field temperature compensating meters to all tactical fuel storage sites.
- Develop and field an automated point of sale device to capture issues from retail and bulk Class III (B) supply points to customers.

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APPENDIX D - ANALYSIS AND RECOMMENDATIONS TO INFORM DEVELOPMENT OF REQUIREMENTS DOCUMENTATION & ENERGY EFFICIENCY KEY PERFORMANCE PARAMETERS

The DCS G4 directed that this study provide analysis and recommendations to inform development of requirements documentation and energy efficiency key performance parameters.

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In the Manual for the Operation of the Joint Capabilities Integration and Development System (JCIDS), dated 31 July 2009, the Joint Requirements Oversight Council (JROC) has defined energy efficiency as a KPP to be selectively applied to programs. The program sponsor must perform an analysis on the use of energy efficiency as a KPP, and if determined that it should not be applied, must provide a summary of the justification will be provided in the CDD.[1]

The JCIDS manual further directs that program sponsors include fuel efficiency considerations in systems consistent with future force plans and approved planning scenarios. Program sponsors must also include operational fuel demand and related fuel logistics resupply risk considerations with the focus on mission success and mitigating the size of the fuel logistics force within the given planning scenarios. They must consider fuel risk in irregular warfare scenarios, operations in austere or concealed settings, and other asymmetric environments, as well as conventional campaigns These assessments will inform the setting of targets and thresholds for the fuel efficiency of materiel solutions.[2]

The Material Systems Directorate of the SCoE has developed guidelines and instructions for the development of energy efficiency KPPs for DOD platforms and systems. The guidelines and instructions are included as ANNEX A of this Appendix. The instruction describes strategic Key Fleet Attributes (KFA) and system level KPPs, considerations for combat and materiel developers, includes example metrics with representative data, and ends with an example KPP development process and a KPP template to be used by the entire development enterprise. Using the process described in this instruction the development community can achieve its goal to field systems with improved energy conversion efficiencies that reduce the overall fuel transport and handling needs that now burden our combat forces today.

Recommendation:

For the development of JCIDS requirements documentation, recommend that the Army adopt the energy efficiency KPP development process developed by the Material System Directorate, Sustainment Center of Excellence.

[1] Manual for the Operation of the Joint Capabilities Integration and Development System, 31 July 2009, B-5.
[2] Ibid., B-6.

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ANNEX A – ENERGY EFFICIENCY KPP DEVELOPMENT, TO APPENDIX D - DEVELOPMENT OF FUEL & ENERGY JCIDS REQUIREMENTS DOCUMENTATION & KEY PERFORMANCE PARAMETERS

(Author's Note: This Annex on an energy efficiency KPP development process was developed by the Material System Directorate, Sustainment Center of Excellence.)

Introduction. This instruction describes the process to develop an energy efficiency key performance parameter (KPP) for Department of Defense (DOD) platforms and systems. The goals of this KPP are to mandate improved energy conversion efficiencies on all platforms and their subsystems and reduce the amount of total energy required for mission accomplishment. Using these goals in tandem will help us reduce overall fuel demand, transport, and handling needs that are now essential for sustaining combat forces today and ensure that our systems and sub-systems are as energy efficient as possible. Treating energy efficiency as an independent variable during combat and materiel development processes helps us define increased efficiency opportunities. Combining these goals with systems level analysis using the fully burdened cost of fuel during the development of life-cycle cost estimates provides us additional insight into the actual cost of ownership and may lead us to more informed investment decisions.

Applicability. Initially, this KPP development process only applies to emerging platforms, systems, and subsystems that obtain their power either directly or indirectly from hydrocarbon energy sources. This includes platform systems and subsystems that obtain power provided by the platform or by associated or complementary auxiliary power units or electrical generation devices. A second increment of this KPP development process will extend energy efficiency goals to equipment powered by a variety of energy sources including disposable batteries. Again the overarching goal of this product is to reduce the amount of energy required as opposed to changing its form. The goals outlined in this KPP development process also apply to current inventory systems when a business case analysis indicates that incremental increases in energy efficiencies during periodic product improvement, engineering changes, or refit are economically prudent and technically feasible.

Background. Conversion efficiency improvements associated with specific technologies are additive. There is currently no single technology with the potential to produce revolutionary improvements in fuel efficiency. However, when the logistics and support implications of incremental efficiency improvements are included, the collective impact of multiple technologies and minor modifications in duty cycles becomes significant. It is also important to note that improving conversion efficiencies will involve many different technologies - different platforms will use different technologies with a consequent demand for different metrics.

This instruction describes strategic Key Fleet Attributes (KFA) and system level KPPs. Included are example metrics with representative data. This instruction ends with an example KPP development process and a KPP template to be used by the entire development enterprise.

Strategic Level Energy Efficiency – Key Fleet Attributes. Strategic level parameters are needed to govern investments in current systems and dictate future expectations. For example, strategic level energy efficiency KFA may cite a reduction in fuel consumption as a percent

reduction metric for a platform family at the fleet level, e.g., “reduce fuel consumption by 20% across the fleet for all ground systems.” This example KFA gives leadership the opportunity to set strategic goals to guide development efforts. Given the KFA, we need to enlist the help of Army Materiel System Analysis Activity (AMSAA) or other like DOD agency analysts to develop baseline data for comparison, business case analyses, and to assist developers identify target fleets or systems. In most applications, associated solutions will encompass both materiel and non-materiel initiatives to achieve desired goals.

Although strategic level KFAs are generally simple, understandable, and easy to incorporate into capabilities documents and policy, they are only the starting point and are difficult to apply to individual systems. They are general by definition and do not address system-specific required capabilities and characteristics that ultimately determine how much energy a platform or system needs to accomplish its mission profile. Consequently, each system or platform must have a unique KPP designed address its required characteristics.

System Level Energy Efficiency KPPs. At the system-level, efficiency KPP must describe desired efficiency objectives. Normally this will consist of a system level metric and a number of supporting attributes or Key System Attributes (KSAs) that contribute to the overall performance requirement. All KPPs must reference a valid quantifiable baseline system or platform for comparison. The KPP must also reference a mission profile and/or a Test Operating Procedure (TOP) to use during analysis. These two elements will assist analysts assemble baseline system or platform configurations for comparison.

When discussing the attributes of a given system, it is important to recognize that fuel or system efficiency and fuel or energy consumption are not the same. Therefore, a system may require two separate and distinct metrics using different analytical approaches to define the KPP. Although individual metrics and capabilities are interdependent, the connection between the two must be evident.

What the Combat & Materiel Developer Must Consider: The combat developer is the author of the KPP and is responsible for the system’s capabilities document. However, KPP development must be a “team” effort. The combat developers need to extract engineering information from the materiel developers and collaborate with the technology development and test and evaluation community to ensure that the requirements written in the KPP are technically feasible and quantifiably testable. The team must consider KPP development at the system level where the resulting design allows for "trade space” onboard that platform keeping in mind that system level trades may affect the system’s capabilities and logistics requirements. To preclude unintended consequences, it is essential the desired performance has a sound operational basis verses arbitrarily increasing performance without regard for the consequences.

Historically, greater capability usually equates to increased fuel consumption. Focusing solely on optimizing other capabilities without regard to fuel consumption is the paradigm that we are trying to change. Therefore, the team must realize logistics realities and operational capabilities are interdependent. In writing the KPP, the team must focus on metrics that are relevant, scalable (e.g., kW/lb) and represent the intent of the user. The requirements team must understand the energy burden associated with each potential requirement and what it means in

relation to achieving the desired capability. Consequently, a major portion of the team's effort must be devoted to creating a system and component level decision tree to define associated power requirements and provide a basis of comparison.

How to Write a System Level KPP: A Case Study: Defining relevant metrics and realistic KPPs for a given system using the team approach is the most practical option to ensure that all relevant information is mined and the KPP and its associated metrics are effectively communicated throughout the developmental process. The following paragraphs provide a case study for a KPP developed for tactical electric power.

In writing a capabilities document for a family of future DOD power sources, an energy efficiency KPP was written for the tactical electric power operational requirements document. The development team mandated reduced fuel consumption for several reasons: (1) to reduce the need to re-fuel during the mission; (2) to reduce fuel infrastructure and (3) to show lifecycle cost savings compared to baseline equivalent systems. Using fuel consumption as a measure of energy conversion efficiency and as the relevant metric clearly showed the operational and financial benefits. This case study summarizes the process for developing this KPP for power generation systems.

The team began this effort by developing power generation systems mission profiles. Mission profiles are needed to understand the operating characteristics required by the system. Once the mission profiles were chosen and agreed upon, the team developed a list of generic technical solutions that had the potential to meet the requirements. During the process, solutions were assessed by Research Development and Engineering Command (RDECOM) and Program Management Office engineers to ensure they were technically feasible. Then the team developed a list of current system component characteristics to use as a baseline during technical comparisons. Viewing the two sets of data side by side enabled the team to develop a relevant metric for the system. In this case, specifying fuel consumption at the system level as a metric was a viable approach because it is measureable and verifiable against the baseline. Energy efficiency per se, was not a good choice since different power generation technologies have correspondingly different efficiencies and our overall goal was to reduce fuel consumption vice improve energy conversion efficiencies. Consequently, it was more informative to specify the fuel consumption metric (e.g., gallons per hour) than to cite an efficiency percentage improvement. The other advantage of using fuel consumption metrics is the relative ease of completing a cost verses benefits analysis. In this way, we are elevating the importance of system efficiency as one way to reduce fuel use. However, more complex systems or those using alternative energy sources may require additional metrics to define desired efficiencies.

Energy Efficiency KPP: How Do You Write It? This is a "step-by-step approach" that shows the process of writing a KPP for fuel consuming systems. This is a summary of many preceding points in this paper. It is important to note again that this is a team approach, in which the core team consists of the User representative (TRADOC), the assigned Program Manager, AMSAA, Army Test and Evaluation Command (ATEC), supporting Research, Development, and Engineering Centers (RDEC), and Joint service members when applicable. The core team must work closely to develop the baseline and determine which metrics best describe the attributes desired in a prospective system. The approach is followed by two examples.

Step 1. Establish the Power and Energy (P&E) Energy Efficiency KPP (EE KPP) Team. The core team must include Combat Development, Materiel Development, ATEC, and RDECOM representatives; others may be added as necessary.

Step 2. Identify strategic efficiency objectives or KFA attributes. These are normally contained in policy statements or Service guidance.

Step 3. Review the system Operational Mode Summary/Mission Profile (OMS/MP). Ensure the OMS/MP accurately describes the duty cycle of the system and its parasitic components as it is the cornerstone of the effort.

Step 4. Create a baseline to use in the analysis. For some systems this might be a similar or predecessor system while emerging systems may require the creation of a surrogate baseline.

Step 5. Develop relevant metrics to use during the comparisons. Use a team approach to select the metrics. Appendix A lists commonly used metrics for ground vehicles.

Step 6. Analyze the baseline system using the metrics against OMS/MP to establish baseline energy requirements

Step 7. Develop engineering and technology thresholds and objectives to be applied to the future system.

Step 8. Write the KPP. Appendix B contains a generic format to use for the KPP.

Energy Efficiency KPPs Responsibilities: Although the user representative is ultimately responsible for writing the KPP, it requires a team effort to ensure the KPP is measurable, defendable, and supports the User's goals. Below is an example of team members and requisite responsibilities Combat Developers should assemble to write a viable EE KPP:

AMSAA: Develop metric examples for generic system families. Examples:

- Non-vehicle fuel consumers: gallons per hour
- Ground vehicles fuel consumers: miles per gallon
- Aircraft fuel consumers: pounds per hour

ATEC: Ensure that any KPP is quantifiable during testing and that test data will be developed to reflect the User's intent and system's mission.

AMSAA / RDECOM P&E Integrated Product Team (IPT): Provide guidance and subject matter expertise for likely achievable threshold and objective magnitudes for the technology trade space for the KPP and system in development. Example technologies:

- Internal / External Combustion Engines
- Electrochemical systems

- Solar-photovoltaic, thermo- photovoltaic, etc

RDECOM P&E IPT Executive Committee (EXCOM): Assist User in development of KPP language for Joint acquisition policy and/or as guidance within the JCIDS process documents, e.g. JCIDS CDD/Capability Production Document (CPD) writer's guide, Joint Requirements Oversight Council Memoranda (JROCM), etc. This language will establish a KPP framework & process with representative metrics that will define how to write tactical-level KPPs (on a case-by-case basis) for a proponent system.

Example: Fuel Consumption KPP for Fuel Consuming Systems. This KPP was developed from the original Tactical Electric Power requirement document fuel consumption KPP mentioned in the case study above. It is important to recognize that this example is straightforward compared to an equivalent KPP for ground vehicles. Therefore, KPP development is not a "cut and paste" exercise. Appendix B provides a guide for recommended language elements that could be used for writing the KPP.

"KPP-Fuel Consumption. The system(s) shall reduce the fuel consumption [*compared to baseline*] over its mission profile and across the platform fleet by an average of 15% (threshold) & 25% (objective). Rationale: Reducing battlefield fuel consumption means fewer fuel tankers on the battlefield, a decreased logistics footprint, reduced reliance on petroleum-derived fuels, increased local energy security, and reduced tanker losses (fewer on the road). The operational imperative to reduce fuel usage will improve Soldier survivability. Reduced fuel needs will consequently reduce refueling operations & exposing Soldiers to hazardous fuel convoy operations."

Several features should be noted here. First, the baseline for this system was easy to establish (the previous Tactical Quiet Generator (TQG) fleet of generator sets. Second, the replacement fleet had the same operational capabilities as the TQG – that is, each generator was replaced in kind at the same power level (a 30kW system replaced the 30kW TQG and so forth). Third, this was established on a fleet wide basis vice individual system, in recognition that different technologies might be required at different power levels.

What If You Need Greater Capability? Invariably, we often want greater performance without increasing or not significantly increasing the need for fuel or more energy. Without describing the underlying physical concepts, any increase in performance normally requires more energy [fuel]. In this case, specifying better fuel economy compared to a predecessor system is problematic if the new system is expected to have greater capabilities. Still, writing a KPP from a combat developer's standpoint could be relatively straightforward when the enabling technology is known. Again, a core team (User-PM-RDEC-AMSAA-ATEC) must do an upfront analysis to determine the most likely solutions and begin to address a KPP using this solution set. This may require market surveys, trades analysis, force effectiveness modeling, or even creating a component level surrogate system to determine the most realistic and achievable KPP(s) given the need for a platform with a greater operational capability's compared to its predecessor system. Therefore, even though we know that greater fuel consumption will result from increased platform weight and capability, we can offset this impact by improving overall system efficiency to the extent practical.

Conclusion. With the continued development of a digitized, network centric battlefield, energy resources are critical to enhancing Future War Fighter capability. In addition, energy efficiency issues are a significant driver for future Army acquisition, planning, and science and technology development. Using the process described in this instruction the development community can meet achieve its goal to field systems with improved energy conversion efficiencies that reduce the overall fuel transport and handling needs that now burden our combat forces today.

APPENDIX A – GROUND VEHICLE METRICS DISCUSSION, TO ANNEX A - ENERGY EFFICIENCY KPP DEVELOPMENT, TO APPENDIX D - DEVELOPMENT OF FUEL & ENERGY JCIDS REQUIREMENTS DOCUMENTATION & KEY PERFORMANCE PARAMETERS

(Author's Note: This Appendix was developed by the Material System Directorate, Sustainment Center of Excellence as part of an energy efficiency KPP development process.)

The following appendix provides a discussion of ground vehicle metrics including definition, potential usage at a systems/unit level, and the differences within an analytical context. The Army Materiel Systems Analysis Activity (AMSAA) will be a key player in the KPP development team recommended in the main section of this document.

AMSAA has modeling capability to estimate vehicle fuel consumption characteristics/metrics for various terrains, power-loading conditions, and mission usage. AMSAA developed the System of Systems Fuel Consumption Prediction Methodology, which enables the Army to study parametric and/or discrete fuel performance of various new technologies (e.g., batteries, engine efficiencies, driveline configurations, driveline components) over a mission profile/power demand profile. Fuel consumption is a function of the duty cycle / power demand (moving and non-moving) and the efficiency of the system to fulfill that demand. AMSAA has applied an engineering approach to studying fuel performance per this theory. AMSAA developed the modeling capability over the last several years and applied it to several major Army programs.

There are several related metrics used to measure fuel consumption performance, which are shown in Table A-1 below. A detailed comparison of each metric use is available in the Power and Energy KPP Development Process white paper written by the RDECOM Power and Energy Integrated Product Team. All these metrics will influence cost and many times, these metrics are misused due to the lack of a common definition or a misinterpretation of the definition and/or question being addressed. A common mistake is directly relating an increase in fuel economy to a proportionate reduction in fuel consumption. This in not completely accurate because fuel economy is based on distance traveled or moving operation while fuel consumption is based on the overall mission including fuel consumed during idle operation. This misinterpretation is made because fuel economy is the predominant fuel metric used in the commercial sector, but it may not be completely applicable in military scenario, depending on the analytical question at hand. Another common misuse is using percent differences without referencing baseline. A percent change represents an implied improvement / degradation in capability versus a common baseline. Percent change implies a comparison, and does not give a metric's magnitude difference. For instance, a 10% decrease in fuel consumed by High Mobility Multi-purpose Wheeled Vehicle (HMMWV) is significantly different from a 10% decrease in fuel consumed by an Abrams tank even though both are stated as a 10% reduction in fuel consumed.

Correct metrics are needed for the particular analysis or issue being addressed. Fuel economy may not be the correct metric for every program. The Army's focus should be on sustainment impact (i.e. demand…fuel consumed and rate of consumption, logistics footprint…number of trucks and personnel needed to supply the demand, and distribution…where to distribute, how much, and how often).

Table A-1: Example Ground Vehicle Fuel Consumption Metrics

Metric *(Typical units)*	Description / Notes
Fuel Economy *(miles per gallon)*	Distance based fuel usage metric. Typically focused on moving operations, but can include non-moving operational fuel consumed for mission calculations. *System Efficiency / Resupply Quantity with impact on Range and Fuel Capacity*
Fuel Efficiency (ton-miles per gallon)	Distance based fuel usage metric similar to mile per gallon, but normalized to weight. It is important to point out that this metric was developed in the commercial sector as transport efficiency for payload and similar vehicles. The intention was not to use gross vehicle weight as the normalization factor. Typically focused on moving operations, but can include non-moving operational fuel consumed for mission calculations. *System Efficiency / Resupply Quantity with impact on Range and Fuel Capacity.*
Burn Rate *(gal/hr or liters/hr)*	Time based fuel usage metric for overall mission or single operating condition. Represents time based demand for a single system for moving and non-moving operation. *Resupply frequency*
Fuel Consumed *(gallons or liters)*	Amount (volume) of fuel consumed for a mission or single operating condition (distance and time are often implied). *Item or Unit Level Demand / Life Cycle Cost ($) Driver*
Useable Fuel Capacity *(gallons or liters)*	System on-board fuel capacity. Can be combined with fuel economy or burn rate to compute range or operating time, respectively. *Resupply quantity and frequency.*
Range *(miles or km)*	Distance a system can move given fuel economy and useable fuel capacity. Often ONLY focused on moving operations. *Distribution Concept / Force Structure*
# Fuel Supply Truck Load Equivalents	Dependent on volumetric capacity of the support truck (e.g., 2.5K gallon HEMTT Fueler). *Unit level calculation and effects force structure depending on fuel distribution unit size (e.g., 4 trucks per unit)*
Percentage Change *(% difference)*	Can be applied to any of above metrics to represent implied improvement / degradation in capability. Requires baseline / context for comparison to determine potential logistics impact. *Metric Dependent*

When choosing a relevant metric, developers must note:

- Percent change in both Fuel Economy & Fuel Consumption are independent of distance and base fuel economy

- The percent fuel consumed changes at a greater rate for decreased % fuel economy as compared to increased % fuel economy (i.e. not symmetric around the baseline axis). For example, decreasing fuel economy 10% increases fuel consumed 11%, but increasing fuel economy 10% only decreases fuel consumed 9%).

Increases in weight and electric power demands (e.g. air conditioning, armoring, and exporting power) could decrease fuel economy from baseline, but technologies improving fuel economy or

reducing exportable power demands could bring the vehicle back to the baseline. In essence, the platform could still use the same amount of fuel and actually be more efficient.

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APPENDIX B – POTENTIAL LANGUAGE FOR POWER & ENERGY KPPS, TO ANNEX A - ENERGY EFFICIENCY KPP DEVELOPMENT, TO APPENDIX D - DEVELOPMENT OF FUEL & ENERGY JCIDS REQUIREMENTS DOCUMENTATION & KEY PERFORMANCE PARAMETERS

(Author's Note: This Appendix was developed by the Material System Directorate, Sustainment Center of Excellence as part of an energy efficiency KPP development process.)

This appendix provides potential language to include in the EE KPP development process: The italic, bold highlights require inputs. Definitions of each follow the generic description.

"KPP- ***[P&E Metric Defined]***. This KPP applies to ***[Scope of Application]***. The system (or systems based on Scope of Application definition) shall reduce the ***[energy metric defined] [compared to baseline]*** over its mission profile and across [end-item-by-end-item comparison OR the platform fleet] by an average of ***X% or X Value*** (threshold) & ***Y% or Y Value*** (objective). ***[Rationale***: Insert summary] [***Trade Space Definition:*** Insert limitations/guidance]

Where:

- ***P&E Metric Defined*** = identify clearly the P&E source metric that is being established or measured. This metric will depend on the system being developed. For example, vehicle, aircraft, generators, etc. may use "Fuel Consumption." Conversely, energy efficiency for batteries (soldier systems) or propulsive systems may be in "Power/Energy Density" (such as kW/kg or kW-hr/kg for weight; or kW/l or kW-hr/liter for volume). AMSAA will be key player in this part the KPP development process.

- ***Scope of Application*** = insert the scope of the KPP requirement, whether being applied to a replacement-in-kind end item, an alternative replacement with different mission profile, new capability, a fleet of end items, and so on. It might include one of the following or one crafted by the team.

    - "… a replacement-in-kind (based on mission profile and application) end item on a one-for-one basis." (Example, improved energy dense battery in soldier system.)

    - "…a replacement-in-kind (based on mission profile and application) system (composed of multiple subsystems but evaluated at the system-wide basis)." (Example, family of generator sets from 5 to 60 kW as in the AMMPS program.)

    - "…an operationally enhanced (based on comparison of mission profiles and performance) but comparable end item." (Example, JLTV replacement for the HMMWV.)

  - "…an operationally enhanced (based on comparison of mission profiles and performance) but comparable system (composed of multiple subsystems but evaluated at the system-wide basis."
  - "…new operational capability composed of discrete end items."
  - "…new operational capability as function of system-wide end items."
  - "…or an alternative rationally developed by the Team based on detailed assessment of mission, operational performance, rationalization against previous systems, achievable technology assessments, and so on."

- ***Compared to Baseline*** = Clearly specify the baseline in detail, by system, system or systems, and/or by empirical or operational data. The baseline should be the comparison to similar/predecessor systems or the most realistically achievable reduction based on available technology & the necessary technical trade-offs among competing system characteristics.

- ***X% or X Value -- Y% or Y Value*** = Enter either the percentage impact or reduction sought for each end item or family of systems OR enter the specific value that must be achieved. For systems in which incremental improvements are acceptable, the percent value may be sufficient. In some systems, it may be critical that a specific value be achieved to achieve the desired operational effectiveness within the energy efficiency paradigm.

- ***[Rationale:]*** = Summarize the rationale driving this particular KPP requirement, and why it necessitates establishment of a KPP. Rationale should highlight the reason energy efficiency is imperative (operational performance, logistics reduction, energy security, force protection, etc.) For example, consider the following example from the AMMPS program:

  "Reducing battlefield fuel consumption means fewer fuel tankers on the battlefield, a decreased logistics footprint, reduced reliance on petroleum-derived fuels, increased local energy security, and reduced tanker losses (fewer on the road). The operational imperative to reduce fuel usage will improve Soldier survivability. Reduced fuel needs will consequently reduce refueling operations & exposing Soldiers to hazardous fuel convoy operations."

[Trade Space Limitations:] Insert a summary of any degree of flexibility in the trades between performance and energy efficiency. For example, at what increase in performance would status quo or even reduced energy efficiency is acceptable.

APPENDIX E – REEVALUATION OF PHASE I STUDY FINDINGS AND RECOMMENDATIONS

The DCS G-4 tasked the study team to reevaluate the recommendations contained in the Phase I Study, "Tactical Fuel and Energy Strategy for the Future Modular Force."

Recommendation #1: Alternative fuel and renewable energy solutions should be researched and developed on an aggressive timeline for implementation to the degree possible in the future Modular Force.

The study team does not support the recommendation to conduct aggressive research and development on alternative fuels. The Army has taken the position that it will not invest in the research and development of alternative fuels, but will evaluate and qualify alternative fuels for use in fuel burning platforms and systems. The U.S. Air Force (USAF), in conjunction with DLA-E, is leading the effort to identify alternative fuels that are a "drop-in" replacement for jet propellant 8 (JP-8), meaning that the alternative fuel mimics the characteristics of JP-8.[1] As alternative fuels are identified, the Army is testing the fuels, including laboratory evaluations, component evaluations, system evaluation and demonstrations, in order to qualify them for use in Army equipment and platforms.[2]

The study team supports the recommendation to aggressively pursue renewable energy sources for integration in the tactical force. There are several compelling reasons for the Army to minimize petroleum-based fuel use, including:

1. Petroleum-based fuel use imposes large logistical burdens, operational constraints and liabilities, and vulnerabilities (otherwise capable offensive forces can be countered by attacking more-vulnerable logistical supply chains – the "rear" is now vulnerable, especially the fuel supply line).

2. Fuel use is characterized by large multipliers and co-factors: at the simplest level, it takes fuel to deliver fuel.

3. Uncertainties about an unpredictable future make it advisable to decrease Army fuel use to minimize exposure and vulnerability to potential unforeseen disruptions in world and domestic fuel markets.

Recommendation #2: Invest in the development and fielding of solar solutions and other alternative energy sources to supplement existing power generation systems and in an intelligent power program to centrally manage power-generation platforms in base camp type locations.

The study team supports this recommendation.

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[1] Kevin Geiss, ODASA (E&P), Comments to the Army Science Board, Washington, D.C., 4 March 2010.
[2] Tank and Automotive Research Development and Engineering Center (TARDEC) briefing to the 4th Annual Alternative Energy NOW Conference, Orlando, FL, 9 February 2010.

Beyond efficiency improvements in existing power generators, solar power clearly shows potential for reducing fuel consumption, especially for small users like isolated combat outposts. Solar is very cyclical by definition, and therefore power generation will still require backup liquid fuel consuming systems and/or energy storage systems.

Micro-grids and intelligent power management systems have already been proven effective in the commercial sector. A micro-grid is an integrated energy system consisting of interconnected loads and distributed energy sources that can operate in parallel with a grid or in an intentional island mode. A micro-grid is characterized by: integrated distributed energy sources, capable of providing sufficient and continuous energy to mission critical loads; independent controls allowing islanding and reconnection with minimal disruption; flexible configuration and operation of the power delivery system.

Hybrid Intelligent Power (HI-Power) is a micro-grid system currently under development by PM-MEP. As envisioned, the HI-Power architecture will provide a modular "plug and play" power grid and intelligent control to command posts. Unique for a tactical power generation and distribution system, HI-Power will accept any type of available power source: military or commercial generator sets, vehicle exported power, energy storage, local utility, hybrid power generation systems and renewable sources. The system will use intelligent power management to dispatch and synchronize the multiple power inputs, allow load balancing, generator cycling, and more efficient use of all available resources, thus minimizing the use of fossil-fuel powered generator sets. The system will also use energy storage for managing load transients, thus increasing the overall energy conversion efficiency with reduced fuel use. Fielding HI-Power has the potential to reduce fuel consumption by power generation systems by 25% or more

Recommendation #3: The Army should institutionalize fuel and energy savings procedures and concepts across all levels. Every effort must be made to reduce the number of fuel grades required on the battlefield.

The study team supports this recommendation regarding the institutionalization of fuel and energy savings procedures and concepts across all levels. Energy Security Goal 1 in the AESIS is reduced energy consumption. To achieve this goal, a shift in Army culture regarding energy is required and the Army must institutionalize the concept of fuel and energy savings across all levels. Army leaders at all levels must be trained to recognize or create opportunities to conserve energy and be prepared to exploit them.

In order to achieve the Army's energy goals, leaders must habitually implement power and energy efficiency practices into daily operations. Leaders and planners must integrate power and energy management into operational planning and execution with care taken to balance the facilitation of effective behaviors and meaningful decisions without distracting from accomplishment of the mission.

Leaders must emphasize the importance of energy efficiency and where possible change current practices and habits to use less energy when conducting training or ground operations. In order to ensure sustained efforts around energy management, leaders must be responsible for not only

providing the framework for energy management, but also for making sure that energy management practices are actually implemented at all levels.

Discussion of reducing the number of fuel grades required on the battlefield is at Appendix B.

Recommendation #4: The Army should continue efforts toward field automation to allow for both asset visibility and accountability of fuel on the battlefield.

The study team supports this recommendation. Further discussion is at Appendix C.

Recommendation #5: Maintain current levels of Prepositioned War Reserve Material Stocks (PWRMS) and Peacetime Operating Stocks (POS) of fuel; continue to partner with other countries to purchase and store fuel; invest in research and development for modernizing fuel consuming vehicles and equipment; and introduce alternative and renewable sources to reduce reliance on and consumption of petroleum-based fuels.

This recommendation actually consists of four recommendations:

1. ***Maintain current levels of PWRMS and POS of fuel***; the study team does not support this recommendation. DLA-E determines PWRMS and POS levels.

2. ***Continue to partner with other countries to purchase and store fuel;*** the study team does not support this recommendation. DLA-E purchases and stores fuel for the Department of Defense.

3. ***Invest in research and development for modernizing fuel consuming vehicles and equipment;*** The study team supports this recommendation. In FY09, the Army consumed over 620 million gallons of fuel for OIF and OEF. Reducing that amount by 20%, or 124 million gallons, would have the effect of reducing the number of fuel truck loads by over 37,500, reducing required fuel convoys by over 2,500, and most importantly, reducing Soldier exposure in convoys by reducing the number of Soldier trips by over 307,000. The value of a 20% reduction in fuel consumption in Soldier risk reduction, logistics support requirements and cost avoidance is clearly evident. Improving the fuel efficiency in legacy vehicle systems and developing and fielding improved efficiency replacement vehicle systems for those that are reaching the end of scheduled life-cycles will result in reducing the overall fuel consumption in vehicles.

4. ***Introduce alternative and renewable sources to reduce reliance on and consumption of petroleum-based fuels***; See comments under Recommendation #1 above for further discussion.

Recommendation #6: The Army should consider establishing a Tactical Fuel and Energy Office to serve as the focal point and advocate for energy initiatives which support tactical deployment. This office would be charged to synchronize efforts across the Army while coordinating with the other services to ensure all efforts reflect the Joint environment.

The study team supports this recommendation. Current DA and DOD energy initiatives and frequently changing operational requirements necessitate a forum with tactical logisticians to advise and make recommendations to the SEE and the Army leadership. There remains no single office/point of contact designated to focus solely on tactical fuel and energy issues. This lack of a designated office results in multiple agencies/offices focusing on tactical energy efforts, but each within their specific area with limited synchronization across the Army.

The Army should consider establishing a Tactical Fuel and Energy Office to serve as the focal point and advocate for energy initiatives which support tactical operations. This office would be charged to synchronize efforts across the Army while coordinating with the other services to ensure all efforts reflect the Joint environment. The office would be accountable for mobility energy matters, develop a comprehensive strategic tactical energy plan, and improve the Army's business processes and practices consistent with current and emerging Army and the DOD concepts and doctrine. The position must also have decision and tasking authority and an adequate staff and resources to address issues confronting the Army. Additionally, the office will establish policy for tactical equipment, as well as oversee the various ongoing projects across the width and breadth of the Army.

Recommendation #7: Reevaluate all applicable fuel standards to ensure the standards are still valid for today's global conditions.

The study team agrees with this recommendation in so much as the Army should continue to evaluate alternative fuels for consumption in tactical equipment and modify equipment specifications to allow for the use of these fuels. See Recommendation #1 for further discussion.

APPENDIX F – PRELIMINARY BUSINESS CASE ANALYSES

The DCS G-4 provided the following guidance for this study regarding preliminary business case analyses: Provide preliminary business case analyses for 2-4 high-payoff energy solutions.

The preliminary business case analyses of the solutions, selected by SCoE, are not intended to contain the analytical rigor of a formal and complete business case analysis but rather high level assessments that identify an opportunity for further detailed analysis. The preliminary business case analyses will address:

- Subject
- Purpose
- Objectives
- Major assumptions and constraints
- Scope of analysis
- Descriptions and preliminary comparisons of alternatives
- Preliminary risk analysis
- Conclusions
- Maturity of recommended solutions
- Specific recommendations for action

The solutions selected by SCoE for analysis and approved by the DCS, G-4 are as follows:

- Deploy a tactical intelligent micro-grid.

- Deploy solar technologies that provide no less than 15kW of tactical level power.

- Deploy a Battle Command data collection integrated solution that permits automated fuel and energy management and operational planning support up to ASCC level.

The preliminary business case analyses are contained in the annexes to this appendix that follow.

Annex A: Tactical Power Management Using Intelligent Micro-Grids

Annex B: Tactical Power Using Solar Photovoltaic Technology

Annex C: Automated Data Collection for Fuel and Energy Management.

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ANNEX A – TACTICAL POWER MANAGEMENT USING INTELLIGENT MICRO-GRIDS, TO APPENDIX F – PRELIMINARY BUSINESS CASE ANALYSES

This preliminary business case analysis addresses the use of tactical intelligent micro-grids as a means of providing intelligent power management to minimize the use of fossil fuels by generators, which ultimately is in support of the goal to reduce dependency on petroleum through reduced energy consumption. Specifically, this analysis focuses on use of intelligent micro-grids in non-traditional Army installations where stand-alone power generators are the primary means of supplied power.

Problem Statement, Current State, Objective and Scope

Problem Statement

No effective method or architecture exists in the tactical environment to reduce power generation fossil fuel consumption through the combined effects of 1) optimizing and managing power generation to match load demand, 2) managing load demand thru automatic load prioritization and control, and 3) supplementing power generation with alternative forms of energy.

Current State

Existing Power Generation: Tactical level power in the expeditionary environment is primarily provided by Army supplied diesel generators. Command posts often utilize multiple and different sizes of these generators to meet their total power needs. The generators are generally connected to loads independent of one another, although the Army is pursuing a Central Power concept which consists of power plants (two or more generator sets operating in parallel) and power distribution equipment[1].

A 2008 Defense Science Board study shows that during wartime, power generators are the single largest fuel consumers on the battlefield accounting for approximately 34% of the fuel consumed[2].

In most instances, power generation at command posts using stand-alone generators results in excess capacity when compared to actual power usage. This occurs for various reasons but is primarily due to the fact that generators are typically sized to support the peak demand periods of their connected loads, resulting in excess generator capacity during non-peak periods. The use of generators operating in parallel for redundancy also leads to excess capacity. Multiple independent generators each add their own excess capacity to the overall

[1] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 28 February 2010.
[2] Derived from table in *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DoD Energy Strategy, February 2008, 44.

system. As larger command posts are established, or multiple command posts are set up at one site, the excess capacity from individual generators begins to multiply[3].

Short term improvements in better matching power generation to power demand are being achieved through application of devices such as the Army's approved Power Distribution Illumination System-Electric (PDISE) and fielding of Central Power for command posts. However, these efforts are only a first step to achieving the maximum generator efficiency possible as neither of these devices attempt to manage power sources or loads and neither allow for integration of alternative forms of energy.

Intelligent Micro-grids: A micro-grid is defined as an integrated power delivery system consisting of interconnected loads and distributed generation sources which as an integrated system can operate in grid-connected or autonomous (islanded) modes[4]. Intelligent micro-grids contain functionality to automatically manage and optimize supply to demand based on predetermined energy management parameters.

Many large corporations (General Electric, Honeywell and Siemens for example) have developed (and continue to enhance) intelligent micro-grid applications which incorporate technologies to manage supply sources and optimize demand loads. The supply sources can include various sources of power producers including alternative energy types such as photovoltaic systems, wind turbines, fuel cells and geothermal.

The Army itself has initiatives in progress to develop and evaluate micro-grid capabilities. Recently, the U.S. Army Tank Automotive Research Development Engineering Center (TARDEC) awarded Honeywell a $4.6 million contract for delivery, testing and demonstration of a micro-grid at Wheeler Air Force Base, Hawaii[5]. Based on the Honeywell Press Release regarding this contract, "…utilizing this system will enable the Army to decrease the number or size – and in some cases, both – of generators needed. The Micro-grid can also interface and control legacy generators"[6]. In addition, in July 2009, the U.S. Army Communications-Electronics Research, Development, and Engineering Center (CERDEC) contracted with Intelligent Power & Energy Research Corporation (IPERC) to develop an "Intelligent Integrated Tactical Power Grid". The IPERC prototype micro-grid controller was demonstrated in Huntsville, Alabama on 15 July 2010.

The Army is also developing and evaluating (at Fort Belvoir, Virginia) an intelligent micro-grid, referred to as "Hybrid Intelligent Power (HI-Power)", for use in the expeditionary environment (see Figure #1). HI-Power is a six-year Office of the Secretary of Defense (OSD) funded effort intended to bring multiple capabilities into play for tactical power distribution and management. The effort is investigating many possible aspects of intelligent grids, to include plug and play capability for identification of loads and sources, load and

[3] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 29 July 2010.
[4] http://www.ieee.ca/epc07/IEEE-EPC2007_PanelSession_RenewableMicrogridApplications.pdf, (Accessed 29 July 2010).
[5] Honeywell Press Release, 14 June 2010, http://www51.honeywell.com/honeywell/news-events/press-releases-details/06.15.10Micro-GridTech.html, (Accessed 07 July 2010).
[6] Ibid.

source management, utilization of alternative energy and energy storage, incorporation of low-quality power sources, and autonomous operation with central control and reporting. HI-Power is not focusing on alternative power developments, but HI-Power like capability is required in order to efficiently utilize alternative power sources in a tactical grid.

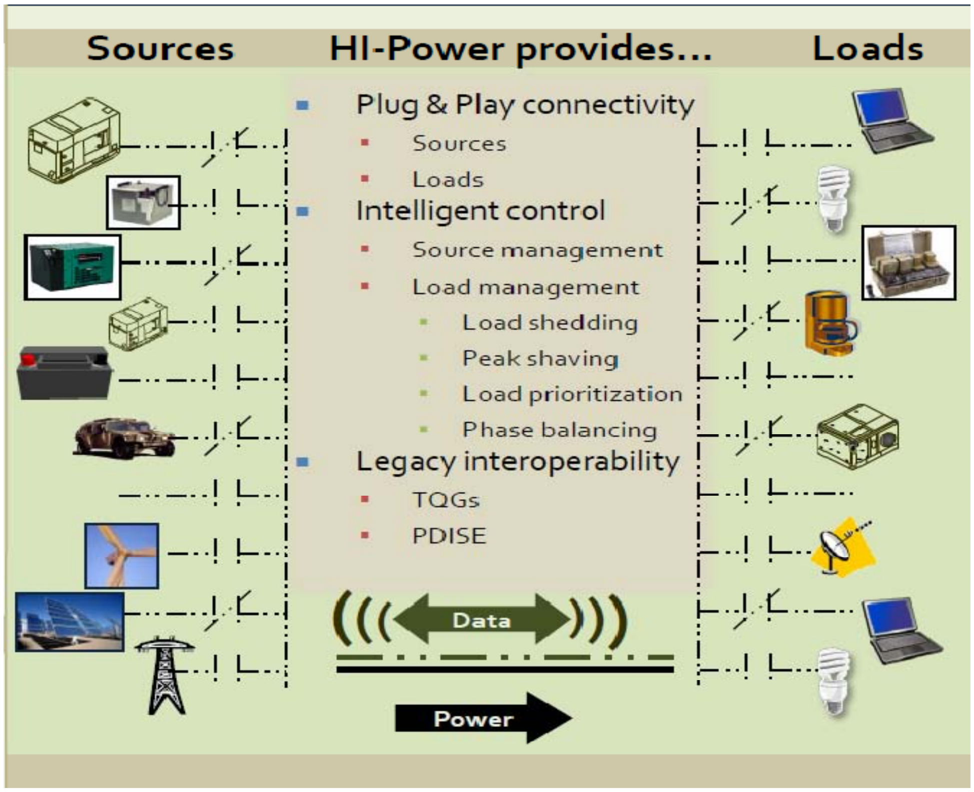

Figure 1

Objective

The intended outcome of applying an intelligent micro-grid at expeditionary command posts would be to reduce generator fuel consumption and offset future increases. The magnitude of potential fuel reductions achieved by use of an intelligent micro-grid at an expeditionary command post would be dependent upon many variables such as the amount and size of generators in use at a particular site, penetration levels of the various forms of alternative energy (if included), the amount of demand being supported at a given site and the level of reduction of excess capacities of existing generators achieved.

The TFEIP lays out the following objective for improved energy use efficiencies:

- By 2028, improved energy efficiencies across tactical platforms and camps that result in an overall 20% reduction in tactical force fuel use from FY12 consumption.

In support of that objective, the TFEIP identifies the following task:

- By FY24, field the HI-Power tactical intelligent micro-grid system.

The intent of this task is to implement an intelligent micro-grid architecture to optimize command post power generation for the ultimate purpose of maximizing efficiencies in power production by generators, resulting in less overall liquid fuel consumption.

Scope of Analysis

This analysis only focuses on application of tactical intelligent micro-grids in non-traditional Army installations in the expeditionary environment for the purposes of optimizing power generation for:

- Battalion level (~15 kilowatt (kW) mission load / ~45kW Environmental Control Unit (ECU) load[7])

- Brigade level (~60kW mission load / ~140kW ECU load[8])

Typical tactical operation center mission loads are fairly constant; varying by about 10%. Environmental control unit loads vary greatly with ambient temperature[9].

It is not the intent of this analysis to evaluate the feasibility of forms of alternative energy such a solar, wind or fuel cells. An intelligent micro-grid could (and should) include provisions for incorporating these forms of alternative energy but the benefits of each type of alternative energy should be addressed in separate analyses.

Major Assumptions and Constraints

Assumptions

The following assumptions are made regarding use of tactical intelligent micro-grids:

1. Current legacy equipment will not be replaced until the end of their planned life-cycles unless replacement is determined to be cost effective or driven by operational necessity.

2. Existing systems can be modified as needed to achieve desired integration of micro-grid technologies.

3. A tactical intelligent micro-grid must be scalable.

[7] Derived from 2008 TOCFEST data provided by Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 05 August 2010.
[8] Ibid.
[9] Ibid.

4. A tactical intelligent micro-grid must be capable of utilizing all forms of power independent of voltage level.

Constraints

The following constraints exist regarding use of tactical intelligent micro-grids:

1. Size/Weight - The system must be conducive for use in an expeditionary environment (e.g. must be generally portable in nature, easily set-up, not semi-permanent or permanently installed and transportable with existing equipment).

2. Environmental – The system must be "militarized" for use in harsh environments.

3. Electromagnetic Interference (EMI) – The system must be operable within the EMI spectrum.

Description of Alternatives Considered

At a high level, alternatives in tactical intelligent micro-grids for the Army are primarily in the level of sophistication of its architecture. For example, in its simplest form, an intelligent micro-grid could function only as a system to manage operation of existing generators by cycling generators on and off-line to match load demand. This would require some level of load management capability to ensure that as loads increase, generation capacity would not be exceeded until an additional generator could be cycled on-line. In its most sophisticated form, an intelligent micro-grid could incorporate and manage multiple forms of power sources (diesel generators, solar, wind, fuel cells, etc.), contain energy storage devices, manage and balance loads and provide usage reporting capabilities. Many levels of sophistication can exist between these two extremes.

The key driver for using an intelligent micro-grid in the expeditionary environment is the potential for generator fossil fuel reductions achieved by application of such a system. The magnitude of potential reductions in generator fuel increases with each level of sophistication mentioned above. However, complexity and cost would increase as well. To that end, this analysis will assess the application and associated benefits of a micro-grid in the two extremes, which are:

- Option #1 - A micro-grid which manages existing power generator sources and loads but does not contain alternative energy sources.

- Option #2 - A micro-grid which manages existing power generator sources and loads and also contains alternative energy sources.

Following is an assessment of these two options.

Comparison of Alternatives

Benefit Comparison

Baseline for Assessment and Comparison: The following baseline will be used in formulating an assessment of utilizing a micro-grid in an expeditionary command post:

Existing Power Generation

Expeditionary command posts utilize Army supplied power generators as the primary means of power and do not rely on host nation power grids. In most instances, the generators at a command post are connected independent of each other and support individual grouping of loads. Usually, there are multiple and varying sizes of generators at any given site.

Generators are typically sized to support peak demand periods which results in excess power generation capacity during off-peak periods. Hypothetically, this can be graphically[10] depicted as seen in Figure #2:

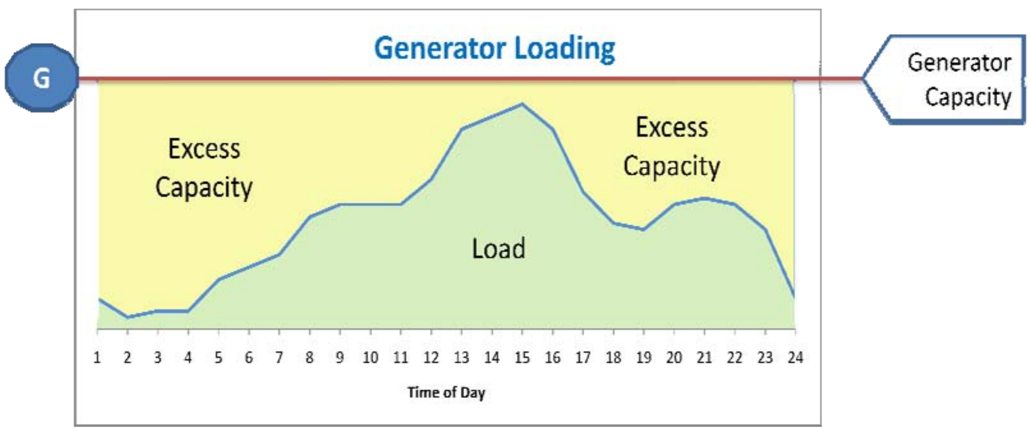

Figure 2

In situations where multiple generators are connected independent of each other, the excess capacity begins to multiply, as evidenced in a recent demonstration of tactical operation centers where generator loading over an eight day period was approximately 50%.[11]

Micro-Grids

Typical micro-grid systems are comprised of:

- *Distributed Generation Sources (micro-sources)* – These could include any combination of fossil fuel power generators, solar photovoltaic systems, wind turbines, fuel cells, hydro systems, waste-to-energy systems or any electricity

[10] Graph created by this paper's author and should not be used as a true representation of actual loading. Graph is hypothetical and is only meant to be used to illustrate a point.
[11] CERDEC briefing, "Reducing Fuel Logistics for Power Generation & Environmental Control", 27 January 2010.

producing device. Each power generation source must have appropriate power electronics for interfacing into device controllers.

- *Loads* **–** Any device that consumes electricity.
- *Intermediate Storage Devices* – Storage devices such as batteries and ultra-capacitors are important components of a micro-grid. These devices provide "ride-through" capabilities during system changes.
- *Controller(s)* – These devices provide the intelligence and control for source and load management based on predetermined control philosophies.
- *Distribution Devices* - These devices provide the ability to shed and restore loads based on pre-defined prioritization schemes.
- *Balance of System* – Point of common connection, properly sized cabling, fuses, circuit breakers, protection relays, sensors, meters, etc.

Assessment of Alternatives

Option #1: A micro-grid which manages existing power generator sources and loads but <u>does not</u> contain alternative energy sources.

Use of a micro-grid solely to manage and optimize existing in-place generators and provide load management (shedding and restoration) at a command post could lead to liquid fuel reductions in situations where multiple generators (two or more) are in use and those generators are operating for portions of their time at less than full load. A micro-grid configuration that could cycle (or step) generators on and off-line (if generators contained auto start/stop capability) in a "load matching" methodology would in effect more closely match power generation to power demand thereby reducing excess generation capacity (see Figure #3 for graphical representation).

Figure 3

Reducing excess generation capacity will ultimately lead to reductions in fossil fuel consumption by the generators. For example, if a command post had five equally sized generators operating at a given moment in time with each generator 50% loaded, then three generators could theoretically support the load in a grid arrangement and two could be shut down; resulting in fuel savings. As loads increase or decrease, the micro-grid controller could start-up or shut down generators as necessary.

Application of a micro-grid in this fashion would require some level of control over loads to prevent the sudden addition of a large load that would exceed current generation capacity. This could be achieved by prioritizing loads (critical, medium or low) and shedding low priority loads or delaying loads coming on-line thru distribution devices until additional generation capacity is automatically started-up and available. Some small amount of excess capacity would most likely have to be maintained to accommodate nominal increases/decreases in loads which could be achieved thru parameters set-up in the micro-grid controller to bring an additional generator on-line or off-line as loads approach a predetermined percent of current generator capacity.

Many variations of load management options could exist and most likely would vary somewhat by command post. If designed properly, once a micro-grid is in place, a micro-grid and its controller and distribution devices could be reconfigured to accommodate changes to command post schemes and load management philosophy. In addition, and once in place, continued enhancements to load management could be achieved. For instance, if an ECU were classified as a medium priority for a particular shelter, then the simple addition of

a motion sensor in that shelter (to determine if the shelter were occupied) tied to the controller could allow the controller to re-prioritize that ECU to a low priority if the shelter were not occupied. The controller could prevent the ECU from starting-up (or reduce the amount of time it runs) until such time the shelter was occupied.

The level of potential generator fuel savings would vary by the number of generators that could be shut down at any given time, the size of generators that could be shut down, and the duration of time that generators could be shut down. Predicting a potential savings Army wide would be difficult given the many variations in specific command post generator arrangements. However, in one specific example based on a Stryker Brigade assessment in a 2008 by CERDEC, implementing a micro-grid with the ability to cycle generators on and off-line resulted in a 17% fuel savings[12].

Maturity of Solution: Development (which has been initiated[13]) and field testing of a “militarized” micro-grid and its controller and distribution device hardware would be required to implement an intelligent micro-grid to manage existing generators and loads. Specific interface designs and auto start/stop capability for source generators and load devices such as ECUs would be required for the platforms the Army utilizes to ensure proper and safe functionality. In some cases, depending on the types of Army generators used in a micro-grid, additional development may be necessary to control both synchronous and asynchronous types of generators operating simultaneously on the same grid.

Recommendation: Fully develop and field test a micro-grid without alternative energy sources as a first step in fielding of micro-grid capability for expeditionary command posts. Complete a formal business case based on learning’s from field testing.

Application of a micro-grid in this fashion will lead to less fossil fuel consumed and is the simplest and most quickly implemented micro-grid option. The system should be pre-disposed, to the maximum extent possible, for the addition of future capabilities to incorporate forms of alternative energy sources. The Army should methodically field validate micro-grids in progressive iterations of sophistication rather than attempting to implement a micro-grid in its most sophisticated form all at once.

Option #2: A micro-grid which manages existing power generator sources and loads and also contains alternative energy sources.

Inclusion of alternative forms of energy sources into a micro-grid represents the most sophisticated and complicated form of an intelligent micro-grid. It would provide the Army with the maximum micro-grid capability to reduce fossil fuels used in generators by providing increased ability to reduce the rated size of some generators and/or shut down some generators for longer durations of time and still support a command post’s total demand. The amount of fossil fuel reductions attributable to use of alternative energy sources in a micro-grid would be dependent upon the types and level of penetration of the

[12] CERDEC briefing, “**H**ybrid-**I**ntelligent POWER ‘HI-POWER’”, March 2008.
[13] PM-MEP has begun development of an intelligent micro-grid. See “Current State” section of this annex.

various forms of alternative energy, energy storage devices and a command post's total power demand.

While this arrangement represents the maximum micro-grid benefit to the Army, it is also the most costly, least mobile and represents the highest risk to success. Many developmental issues still exist with including alternative forms of energy into a micro-grid; the most significant being that high penetration levels of intermittent forms of alternative energy into a micro-grid can potentially cause grid instability when that intermittent source suddenly shuts down (i.e. sun goes behind a cloud when using solar power). In addition, control algorithms for the micro-grid controller become more complicated and possibly more difficult to account for failure modes. Second order effects also become more significant in this scenario which could off-set the primary benefits of a micro-grid. For example, deployment and mobility become more significant issues in that a system that includes alternative forms of energy and energy storage devices could become so bulky and time consuming to set up that it would not be practical.

Maturity of Solution: The Army has established a test bed at Fort Belvoir and begun developmental efforts with multiple contractors of an intelligent micro-grid (HI-Power program[14]) that will be capable of incorporating alternative forms of energy. Overall, HI-Power is estimated to be in the Technical Readiness Level (TRL) range of 5-6[15]. Representatives from the office of the Project Manager - Mobile Electric Power (PM-MEP) are planning to take part in a demonstration of the HI-Power concept in the fall of 2010. If successful, this would put HI-Power at a TRL 7[16].

Development and testing of the same components identified in Option #1 are required for this option as well. In addition, "militarized" energy storage devices must be developed and field validated for use in a system that includes alternative energy sources.

Recommendation: Finalize development of the HI-Power concept to determine the longer term viability and benefits of implementing a micro-grid with alternative forms of energy in the expeditionary environment. A HI-Power type program will ultimately provide the basis for establishing requirements and specifications for a micro-grid system that incorporates forms of alternative energy.

As stated in Option #1, the Army should methodically field validate micro-grids in progressive iterations of sophistication rather than attempting to implement a micro-grid in its most sophisticated form all at once. Fielding of a micro-grid scheme which includes alternative forms of energy should be the final step in implementing micro-grids in the expeditionary environment.

[14] See "Current State" section of this annex.
[15] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 22 July 2010.
[16] Ibid.

Second and Third Order Effects

Beyond providing potential fuel reductions associated with generators, there are additional benefits and some drawbacks to utilizing micro-grid systems. Following are just some of those benefits and drawbacks.

Benefits:

- Reductions in fossil fuel for generators contribute to reductions in fuel convoys for the Army in expeditionary environments.

- Increased individual generator loading, thru source management and optimization, minimizes the potential for generator "wet-stacking" (build-up of un-burned fuel or carbon in the exhaust system of a diesel engine resulting from prolonged light load conditions).

- Reductions in generator run times decreases greenhouse gas emissions.

- Reductions in generator run times could decrease spare parts requirements for generators due to less generator run hours.

Drawbacks:

- Additional training in the employment and use of micro-grids will be required for Army personnel.

- Additional material will be required for deployment (micro-grid components).

Cost Information

A multitude of variables can affect the cost of an intelligent micro-grid system and its corresponding return on investment (ROI). For example, some areas affecting system costs include architecture selected, inclusion level of alternative forms of energy, level of sophistication of a micro-grid system, installation location, and military specifications for a system. ROI can be affected by such variables as amount of fuel reductions achieved by use of a micro-grid at a particular site, the fully burdened cost of fuel (FBCF) for generators for a specific location and the life cycle cost of a micro-grid system which includes maintenance, training and spares.

A general estimated cost for a fully installed intelligent micro-grid cannot be predicted at this time due to the lack of Army requirements, type of architecture desired, specifications, and vendor selection for such a system.

The level of potential fuel savings by type of location also cannot be precisely predicted until a specific architecture is tested in a representative environment. However, based on initial

modeling for HI-Power, fuel savings could be in the range of 25%[17]. To put this into perspective, if a command post operated four 15kW generators to meet its total power needs, the four generators would be consuming a total of approximately 4.8 gallons/hour[18] of fuel (1.2 per generator). A 25% fuel savings would equate to 1.2 gallons/hour, 10,500 gallons/year (1.2 x 24 x 365).

NOTE: Fuel savings by location will no doubt vary depending on mixes of generator sizes at each location.

Preliminary Risk Analysis

The risks identified below represent the most significant risks that can impact fielding of intelligent micro-grid systems in the expeditionary environment.

Each risk has an associated:

- Probability of occurrence - ranked high, medium or low.
- Impact of occurrence - ranked high, medium or low.
- Mitigation strategy - classified as Avoid, Mitigate, Accept or Transfer.
- Sensitivity area – highest affected area related to Scope, Schedule or Cost.

Risk	Probability of Occurrence	Impact of Occurrence	Mitigation Strategy	Sensitivity Area
1. Adequate funding not made available to support phased developments of micro-grid concepts.	High	High	Accept	Schedule
2. Unanticipated issues surface after development.	High	Medium	Mitigate (by phased development/testing)	Scope
3. Fielded micro-grid systems do not function as intended.	Medium	Medium	Mitigate (by testing in representative environment)	Cost (payback)
4. Micro-grid systems cannot be functionally integrated with all major types of existing Army generators.	Medium	Medium	Transfer (by requiring micro-grid supplier(s) to design appropriate interfaces)	Scope

[17] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 21 July 2010.
[18] 1.22 gallon/hr per 15kW generator derived from briefing from Project Manager-Mobile Electric Power, "Tactical Electric Power Overview", Army Science Board Brief, 3 March 2010.

Conclusions and Recommendations

Conclusions

Intelligent micro-grid systems can be utilized by the Army in two primary application fashions, which are:

- Option #1 - A micro-grid which manages existing power generator sources and loads but does not contain alternative energy sources.

- Option #2 - A micro-grid which manages existing power generator sources and loads and also contains alternative energy sources.

The magnitude of potential fuel reductions achieved by use of an intelligent micro-grid at an expeditionary command post would be dependent upon variables such as quantity and size of generators in use at a particular site, penetration levels of the various forms of alternative energy (if included) into a micro-grid, the amount of demand being supported at a given site, environments (which heavily affects ECU loads) and the level of reduction of excess capacities of existing generators achieved.

Currently, the Army does not have requirements and specifications established for a micro-grid system. Once established, a more in-depth analysis must be performed on selected architectures based on the ability to down size a generator, or to shut down a generator for short periods of time, to determine if the levels of liquid fuel reductions are significant enough to justify the life cycle costs of a micro-grid system.

Recommendations

1. Develop and evaluate, at representative expeditionary command posts, intelligent micro-grids in two progressive phases.

- Phase 1 - A micro-grid which manages existing power generator sources and loads but does not contain alternative energy sources.

- Phase 2 - A micro-grid which manages existing power generator sources and loads and also contains alternative energy sources.

Development and evaluation of intelligent tactical micro-grids in a phased approach minimizes initial development time and risks of failure. A phased approach also allows the Army to implement a basic micro-grid more quickly to achieve fossil fuel reductions. Outcomes from each progressive stage of development could then be utilized in spiral development cycles to more precisely define benefits and requirements for the next level of sophistication.

2. Perform a more in-depth business case analysis on each phase once evaluation in a representative environment is complete.

Cost savings determinations for battalions and brigades can become very complex assessments based on mission scenarios and the many other factors previously mentioned. At such time a formal business case is performed, the Army will need to determine a basis for use in determining Return on Investments - an average fuel savings based on analysis of many different configurations or an average fuel savings of a small number of representative systems.

ANNEX B – TACTICAL POWER USING SOLAR PHOTOVOLTAIC TECHNOLOGY, TO APPENDIX F – PRELIMINARY BUSINESS CASE ANALYSES

This preliminary business case analysis addresses the use of solar photovoltaic (PV) devices as a means of providing supplemental power in the tactical environment, which ultimately is in support of the tactical fuel and energy goal to reduce dependency on petroleum through increased use of renewable and alternative energy sources. Specifically, this analysis focuses on use of PV devices in non-traditional Army installations where stand-alone fossil fuel consuming power generators are the primary means of supplied power. In addition, this analysis considers the use of PV devices in the absence of an intelligent micro-grid (potential future capability) which may incorporate PV devices.

Problem Statement, Current State, Objective and Scope

Problem Statement

The Army desires to reduce its dependence on petroleum by supplementing tactical level power generation with renewable/alternative forms of energy. Solar, as a form of alternative and renewable energy, offers a significant potential for supplemental power, given that sunlight is generally readily and widely available in the tactical environment.

Current State

Existing Power Generation: Tactical level power in the expeditionary environment is primarily provided by Army supplied fossil fuel consuming power generators. Command posts often utilize multiple and different sizes of these generators to meet their total power needs. The generators are generally connected to loads independent of one another, although the Army is pursuing a Central Power concept which consists of power plants (two or more generator sets operating in parallel) and power distribution equipment[1].

A 2008 Defense Science Board study shows that during wartime, power generators are the single largest fuel consumers on the battlefield accounting for approximately 34% of the fuel consumed[2].

In most instances, power generation at command posts using stand-alone generators results in excess capacity when compared to actual power usage. This occurs for various reasons but is primarily due to the fact that generators are typically sized to support the peak demand periods of their connected loads, resulting in excess generator capacity during non-peak periods. The use of generators operating in parallel for redundancy also leads to excess capacity. Multiple independent generators each add their own excess capacity to the overall

[1] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 28 February 2010.

[2] Derived from table in *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DoD Energy Strategy, February 2008, 44.

system. As larger command posts are established, or multiple command posts are set up at one site, the excess capacity from individual generators begins to multiply[3]. Also, of the power being consumed at command posts, 50-90% is used for environmental control units (ECU)[4].

Flexible Solar Panel

Solar Tent

Photovoltaic Devices: The Army currently has several on-going initiatives related to applications of PV devices in the expeditionary environment. To date, most of these initiatives have primarily focused on utilizing PV devices as a source of low level power. One such example of this is a flexible solar panel (<100 watts) utilized in a Rucksack Enhanced Portable Power System (REPPS) that can provide power for requirements such as powering small electronic devices and battery re-charging[5]. Another example is a "Solar Tent" that incorporates flexible solar panels which could provide 1 to 2 kilowatts (kW) of power which can be utilized for a variety of purposes ranging from lighting to ventilation to power for field communication radios, global positioning system (GPS) devices, and recharging satellite phones and laptop computers[6].

Initiatives such as these demonstrate the potential for utilizing PV devices as a means of stand-alone or supplemental power on a small scale. These types of small scale applications lend themselves to high portability and flexibility of application. In addition, these type applications could provide for a source of power where power is otherwise not readily available.

Applying a PV system to supplement existing power generation at expeditionary command posts has the potential to reduce generator fuel consumption (or offset future increases). The magnitude of potential fuel reductions would be dependent upon a PV system size, configuration and specific application. An example of one application would be to utilize a PV system in parallel with an existing generator to supplement the peak demand period that the generator has to support. This could potentially allow for use of a smaller, less fuel consuming generator to support the balance of the load if the PV sourced power were reliable and sustained via use of energy storage devices such as a battery system. Another example would be to utilize a PV system on non-critical loads and shut down the associated generator during times when PV power is available, thus saving generator fuel. Each of these examples would offer different levels of potential fuel reduction based on the amount and duration of power provided by the PV system and the corresponding reduction in generator produced power.

Objective

The TFEIP lays out the following objective for improved energy use efficiencies:

[3] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 29 July 2010.
[4] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 29 March 2010.
[5] CERDEC, "Reducing Fuel Logistics for Power Generation & Environmental Control", 27 January 2010.
[6] Ibid.

- By 2028, at least 25% of energy used for tactical level power generation will come from alternative and renewable sources.

In support of that objective, the TFEIP identifies the following task:

- By FY28, field solar technologies that provide at least 15kW of tactical level power.

The intent of this task is to implement a PV architecture to supplement command post power needs for the ultimate purpose of reducing power production by existing generators, resulting in less liquid fuel consumption.

Scope of Analysis

The intended application of a tactical PV architecture to supplement power generation would be for non-traditional Army installations in the expeditionary environment and would include:

- Battalion level (~15kW mission load / ~45kW ECU load[7])

- Brigade level (~60kW mission load / ~140kW ECU load[8])

Typical tactical operation center mission loads are fairly constant; varying by about 10%. Environmental control unit loads vary greatly with ambient temperature[9].

It is not the intent for a PV system to be a primary means of power; only a means to supplement existing power generation. Solar is very cyclical by definition, and therefore power generation would still require backup liquid fuel consuming systems and/or energy storage systems.

Excluded from this analysis are applications of PV devices specifically for powering dismounted soldier devices.

Major Assumptions and Constraints

Assumptions

The following assumptions are made regarding use of PV devices to supplement command post power generation:

1. PV systems applied in the tactical arena will not be the primary means of power; rather, only a means to supplement existing power generation.

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[7] Derived from 2008 TOCFEST data provided by Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 05 August 2010.
[8] Ibid.
[9] Ibid.

2. Total PV power capacity does not have to be supplied from one individual PV system; it can be supplied from several smaller independent systems (i.e. three 5kW PV systems could provide a total of 15kW to meet an objective of 15kW total).

3. Current legacy equipment will not be replaced until the end of their planned life-cycles unless replacement is determined to be cost effective or driven by operational necessity.

4. Existing systems can be modified as needed to achieve desired integration of PV technologies.

Constraints

The following constraints exist regarding use of PV systems in the tactical environment:

1. Size/Weight - A system (or systems) must be conducive for use in an expeditionary environment (e.g. must be generally portable in nature, easily set-up, not semi-permanent or permanently installed and transportable with existing equipment).

2. Environmental - Components must be capable of operating in harsh environments.

3. Available Sunlight – PV systems must have an unobstructed view of sunlight.

<u>Description of Alternatives Considered</u>

Alternatives in PV systems can be many, particularly in the specific application of a PV system and the selected configuration to achieve a desired outcome. Available sunlight, solar panel efficiencies, system size, system form (fixed versus flexible), system configuration (with or without batteries), operating voltages, desired portability and desired power (watts) are just some of the parameters that all interrelate to affect the benefits offered by a PV system.

Fundamentally, any PV system arrangement could be applied to provide some level of supplemental tactical power for the Army. The magnitude of potential reductions in existing generator fuel achieved by supplementing the generators with PV power will vary based on the amount and duration of PV power available to off-set power produced by generators.

In the traditional use of a grid connected PV system, a power consumer would utilize a PV system to reduce the amount of power a consumer purchases from a provider (e.g. local utility company), thus saving a consumer money. The consumer only pays a provider for the amount of power the consumer uses from them and the cost of any excess generator capacity is borne by the provider. In the case of the Army, the Army itself is both the provider and the consumer of power in the tactical arena and unless generating capacity can be reduced there would be no significant benefit to the Army. Therefore, this analysis will primarily focus on:

> ***"Is a PV system an effective option for supplementing tactical level power generation for the purpose of reducing generator fuel consumption?"***

To analyze that higher level question, a PV system should be considered holistically in conjunction with how the Army utilizes existing power generation equipment in the tactical environment, keeping in mind that the Army is both the provider and the consumer of power. To that end, application of a PV system should be considered in three primary fashions, which are:

- Option #1 - A PV system used in a stand-alone arrangement without backup generators.
- Option #2 - A PV system connected in parallel to existing power generation equipment **without** a battery or similar storage system.
- Option #3 - A PV system connected in parallel to existing power generation equipment **with** a battery or similar storage system.

In Option #2 and Option #3, a generator could run simultaneously with the PV system. Option #3 would be the only option where generators could be shut down if they are connected to critical loads.

Following is an assessment of these three options.

Comparison of Alternatives

Benefit Comparison

Baseline for Assessment and Comparison: The following baseline will be used in formulating an assessment of utilizing PV systems as a means of supplementing tactical power generation:

Existing Power Generation

Expeditionary command posts utilize Army supplied power generators as the primary means of power and do not rely on host nation power grids. In many cases, the generators at a command post are connected independent of each other and support individual groupings of loads. Usually, there are multiple and varying sizes of generators at any given site.

Generators are typically sized to support peak demand periods which results in excess power generation capacity during off-peak periods. Hypothetically, this can be graphically[10] depicted as follows in Figure #1:

[10] Graph created by this paper's author and should not be used as a true representation of actual loading. Graph is hypothetical and is only meant to be used to illustrate a point.

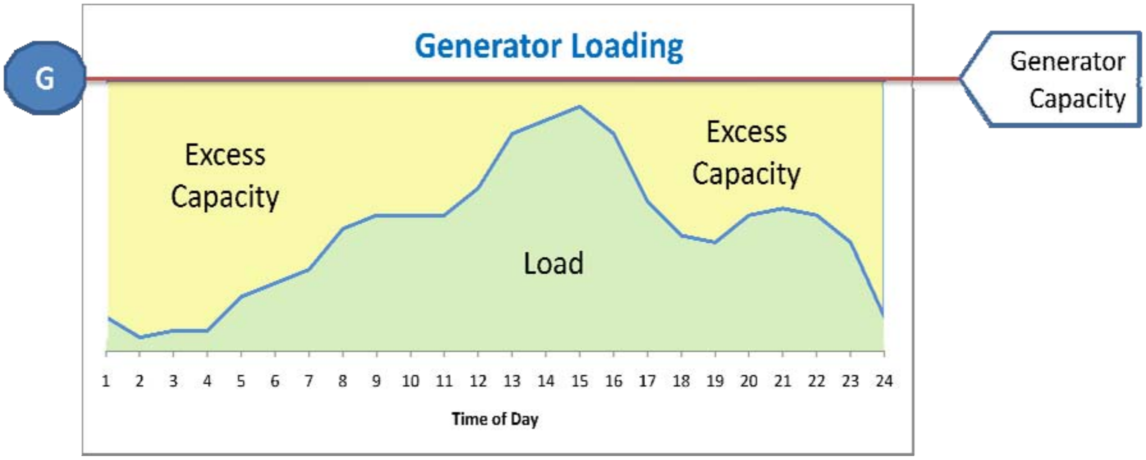

Figure # 1

In situations where multiple generators are connected independent of each other, the excess capacity begins to multiply, as seen in a recent demonstration of tactical operation centers where generator loading over an eight day period was approximately 50%.[11] Even if a grid were in place that maximized the use of power generation equipment and minimized the excess capacity, there would always still be some level of excess capacity, although not as great.

PV Systems

PV systems are made up of interconnected components, each with a specific function. One of the strengths of PV systems is modularity. As needs grow, individual components can be replaced or added to provide increased capacity. Following is a brief overview of a typical PV system (see also Figure #2).

- *Solar Array* – The solar array consists of one or more PV modules which convert sunlight into DC voltage. The modules are connected in series and/or parallel to provide the desired voltage and current levels. The array is usually mounted on a metal structure and tilted to face the sun. The DC voltage can be used to charge a battery bank and/or be converted directly into AC voltage.

- *Charge Controller* – The charge controller maintains the batteries (if batteries are used) at the proper charge level and protects them from overcharging.

- *Battery Bank* - The battery bank (if used) contains one or more deep-cycle batteries, connected in series and/or parallel depending on the voltage and current capacity needed. The batteries store the power produced by the solar array and discharge it when required.

- *Inverter* - The inverter converts the DC power from the solar array (if no batteries are used) or the batteries into 120 volt AC power. The inverter can (if required) also

[11] CERDEC briefing, "Reducing Fuel Logistics for Power Generation & Environmental Control", 27 January 2010.

synchronize the AC voltage to a primary AC source (e.g. generator or grid). If 240 volts AC is needed, then either a transformer is added or two identical inverters are series-stacked to produce the 240 volts.

- *Balance of System* - These components provide the interconnections and standard safety features required for any electrical power system. These include an array combiner box, properly sized cabling, fuses, switches, circuit breakers and meters.

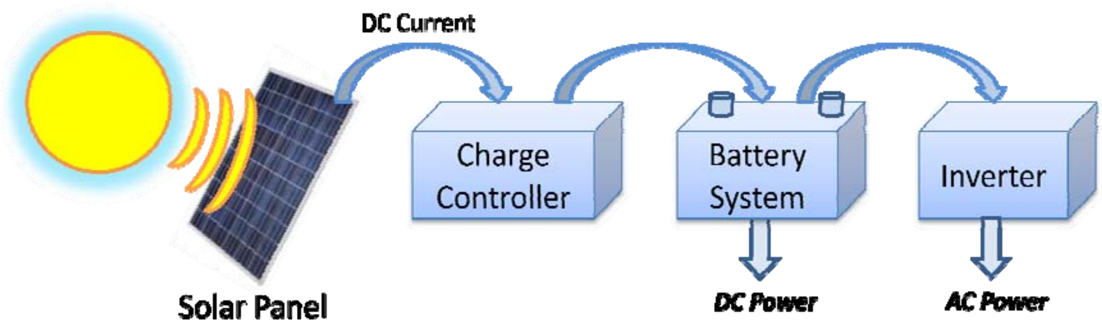

Figure # 2

In a PV system where batteries are used (which is generally the case), the heart of the PV system can be characterized as basically the solar panels and the batteries. The solar panels provide the source of power for maintaining a charge in the batteries and the batteries provide a continuous supply of power (until the batteries are depleted to a specified level) even when there is no available sunlight. PV systems can however be used without batteries but power would only be available when there is adequate sunlight. Utilizing batteries (or any energy storage system) provides for power when adequate sunlight is not present.

Power generated from a solar panel is not constant since it is dependent upon the sun. In addition, the power level of a solar panel will vary based on the panel's angle of incidence to the sun with the most power being generated when the sun is facing directly into the solar panel. A solar panel's power output begins to diminish as the sun moves away from directly facing into the solar panel. Additional hardware can be added to a PV system to track the movement of the sun and continuously adjust the panel's position to the sun which would increase the amount of "peak power time" of a PV system. However, this adds cost and complexity to a PV system.

Assessment of Alternatives

Option #1: Stand-alone PV systems without back-up generators

PV systems utilized in a stand-alone mode without a generator backup would most likely only be employed by the Army in situations where assured power is not required or power is otherwise not available. A stand-alone system would typically include some amount of battery storage capacity. The amount of time that power would be available in a stand-alone system is directly related to the availability of adequate sunlight to charge a battery system,

the size of the battery system and the amount of load drawing on the battery system. Figure #3 below illustrates a typical arrangement for a stand-alone PV system.

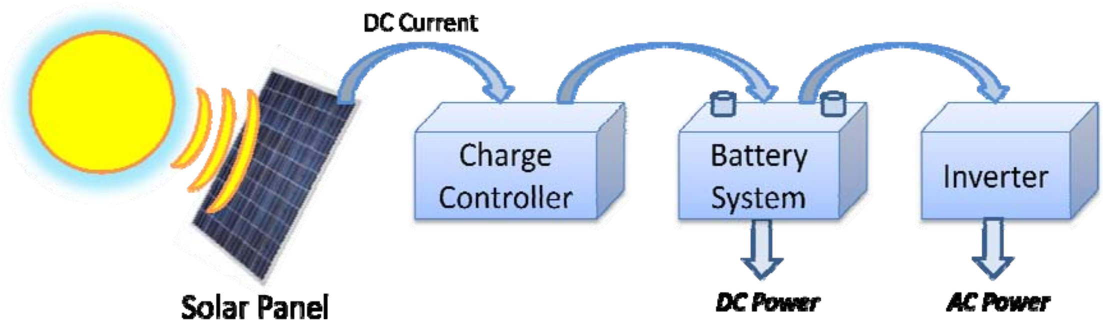

Figure # 3

Given the Army's need to have assured power at command posts for the biggest portion of its loads, it is unlikely that a applying a PV system in a stand-alone arrangement without back-up generators would be an option the Army would employ on a large scale. However, there could be some limited opportunities to utilize a stand-alone PV system to provide power to non-critical loads that do not require "always on" power and reduce some of the requirement for generator produced power (thus saving some fuel). This however would require that the connected load be non-critical since a PV system installed in this fashion represents a "single point of failure" and will shut down power to the devices connected to the PV system when the battery system depletes to a certain level.

Maturity of Solution: Proven technology currently exists in the commercial world to support a stand-alone type PV configuration. Although the technology is well developed, there are improvements and modifications occurring regularly in areas such as production processes, solar panel efficiencies and available solar panel forms. Use of commercial-off-the-shelf (COTS) devices versus the need to "militarize" a PV system and its energy storage devices for expeditionary environments would need to be determined by the Army.

Recommendation: Use of a PV system in a stand-alone mode is recommended for non-critical loads only. A more detailed analysis must be performed based on specifically identified loads that could be displaced from a generator to determine if the levels of liquid fuel reductions are significant enough to justify the life cycle costs of a PV system.

Option #2: PV Systems in Parallel with Generators (without battery systems)

A PV system utilized without a battery storage system (or similar storage system) as depicted in Figure #4 can only provide supplemental power when there is adequate sunlight. In addition, the PV system power level will diminish as the sun moves away from facing directly into the solar panel.

The amount of load supported by the power generated from the PV system could partly offset the amount of load a generator is supporting during the period the PV system is providing power. Reducing the load on a generator, even if it still runs, would reduce some amount of

fuel used by that generator (generators use less fuel at lighter loads although their overall efficiency goes down and the potential for "wet-stacking" increases). The amount of fuel savings for the generator would be dependent upon the size of the generator, the total demand on the generator and the load that the PV system could assume from the generator. If for example a 60kW generator had a continuous load of 45kW for one hour (45 kilowatt hours) and a PV system could reduce that amount by 15kW for that same hour, then the generator would provide only 30kW for that hour versus 45kW. This would roughly translate to one gallon of less fuel used by the generator for that hour[12]. The amount of hours per day this could be achieved is directly related to amount of hours of adequate sunshine.

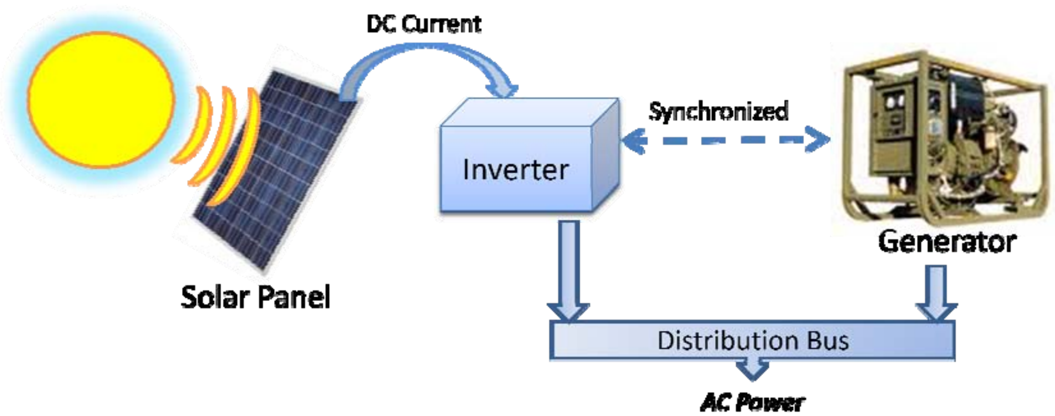

Figure # 4

Use of a PV system as discussed in this option to reduce the load on a generator could create some secondary negative benefits such as increased potential of generator "wet-stacking" (leading to increased maintenance) due to operating the generator for longer periods of time at lighter loads. Ideally, generators (commercial versions) should not be operated for a prolonged period of time below 40% of the rated output[13].

In an arrangement where no battery system is utilized in a PV system, a generator would still need to be sized to be capable of supporting its entire load as the supplemental power from a PV system would not be consistent and as reliable as a system with batteries.

Maturity of Solution: Proven technology currently exists in the commercial world to support paralleling a PV system (without a battery system) with a generator. Specific interface designs would be required to parallel a PV system with the specific generator platforms the Army utilizes to ensure proper and safe functionality. As stated in Option #1, although PV technology is well developed, there are improvements and modifications occurring regularly in areas such as production processes, solar panel efficiencies and available solar panel

[12] Derived from fuel usage data for generators, EmergencyPower.com: Diesel Generator Fuel Consumption, http://www.emergencypower.com/diesel-fuel-consumption/, (Accessed 7 June, 2010).
[13] "Diesel Engine Wet Stacking", http://www.dieselgeneratorsite.com/Generator%20Selection.html, (Accessed 17 June 2010).

forms. Use of COTS devices versus the need to "militarize" a PV system for expeditionary environments would need to be determined by the Army.

Recommendation: While theoretically possible, use of a PV system in parallel with a generator without a battery storage system is generally not recommended for use by the Army on a large scale in the tactical environment. Use of a PV system in this fashion does not maximize the true benefits of a PV system. For instance, when there is excess power available from a PV system due to lighter load periods then that power would permanently be lost since there would be nowhere to store it.

If this arrangement were to be used, it should only be utilized a means of supplementing existing generator produced power as long as there is no reduction in the rated size of the corresponding generator. The generator should still be sized to support its entire load as this type of arrangement of a PV system is not a reliable source of supplemental power. A more detailed analysis must be performed based on the amount of generator load reduction that could be achieved to determine if the levels of liquid fuel reductions are significant enough to justify the life cycle costs of a PV system.

Option #3: PV Systems in Parallel with Generators (with battery systems)

A PV system utilized with a battery storage system (or similar storage system) as depicted in Figure #5 can provide supplemental power even when the sun is not shining. The amount of time the PV system can provide power in the absence of adequate sunlight will be dependent upon the size of the battery system and the amount of load drawing on that battery system; the more battery capacity there is, the longer power can be provided.

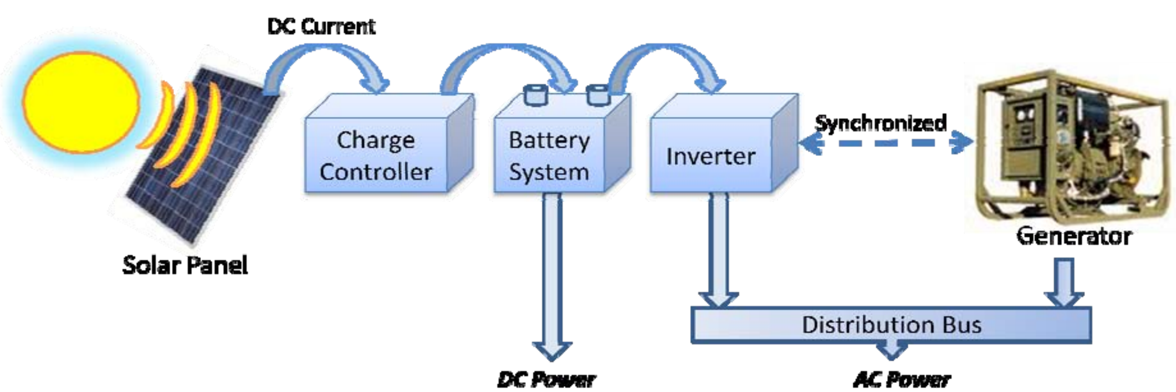

Figure # 5

A PV system with a battery storage system would provide the highest degree of reliability in consistent supplemental power and afford a higher degree of opportunity to reduce the rated size of a generator and/or shut down a generator for short durations of time. For example, if the battery system were sized correctly to supplement a generator's peak demand duration, then a smaller less fuel consuming generator could be used in place of the original generator. Aside from using less fuel, the average load to rated capacity ratio on the smaller generator would increase which would improve the generator efficiency and reduce the potential for

generator "wet-stacking". Additionally, with a battery system, the generator could be shut down and power could be provided from the battery system until the batteries deplete to a certain level. The amount of fuel savings for shutting down a generator will vary based on the size of the generator, the duration it could be shut down and the load it was supporting at the time. For example, using a 20kW generator, if the load on that generator were 5kW for 3 hours (15kW hours) and the battery system were sized to support 15kW hours; the generator could potentially be shut down for 3 hours. The resulting fuel savings would be roughly 2 gallons of fuel for that period[14].

Additional opportunities exist with a battery system to take additional steps to assure reliability of the supplemental power and further reduce dependence on the sun. For instance, as stated previously, some level of excess capacity will always exist with utilizing generators. Harnessing that excess capacity to additionally act as a source of battery charging would further ensure the system would continue to work even in periods of extended "low light" days (several days in a row of cloudiness). The excess capacity from the generator could charge the battery system in the absence of adequate sunlight[15]. Figure #6 highlights this basic concept.

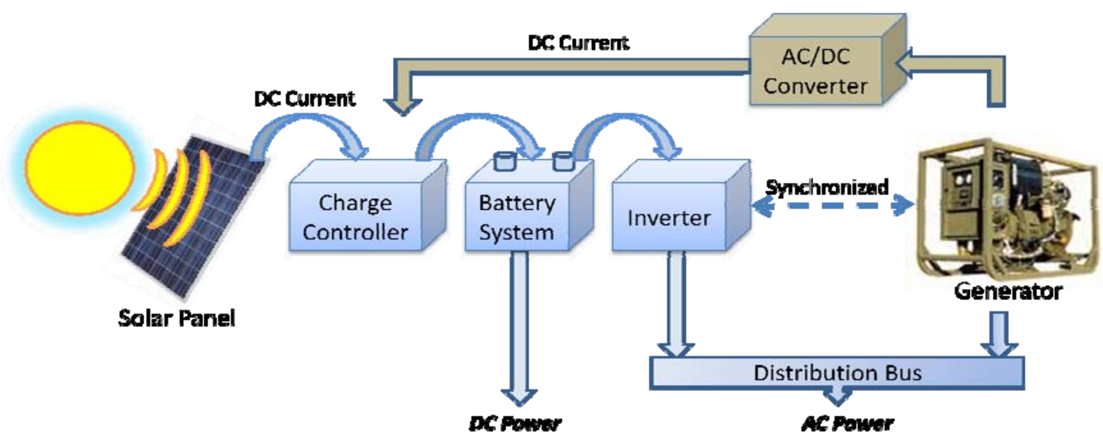

Figure # 6

Maturity of Solution: Similar to Option #2, proven technology currently exists in the commercial world to support paralleling a PV system that includes a battery system with a generator. Specific interface designs would be required to parallel a PV system with the specific generator platforms the Army utilizes to ensure proper and safe functionality. Similar to Option #1 and Option #2, there are improvements and modifications occurring regularly for PV technologies in areas such as production processes, solar panel efficiencies and available solar panel forms. Use of COTS devices versus the need to "militarize" a PV system and energy storage devices for expeditionary environments would need to be determined by the Army.

[14] Derived from fuel usage data for generators, EmergencyPower.com: Diesel Generator Fuel Consumption, http://www.emergencypower.com/diesel-fuel-consumption/, (Accessed 7 June, 2010).
[15] Would require additional hardware, controls and system protections.

Recommendation: Use of a PV system in parallel with a generator with a battery storage system should be the preferred option for the Army. It offers the highest degree of flexibility for supplementing tactical power for the Army and the maximum opportunity to reduce liquid fuel consumption using PV systems. Additionally, if an associated generator were routinely shut down during use of the PV system as described above, the Army should incorporate an "auto start/stop" feature for the generator to automatically start and stop the generator when the battery system reaches specified levels of storage capacity. [NOTE: *While not specifically for the purposes described in this document, PM-MEP is currently working with a solar vendor (Solar-Stik) to develop an auto-start kit for the 3kW MIL-STD generator*[16].]

A more detailed analysis must be performed based on the ability to down size a generator, or to shut down a generator for short periods of time, to determine if the levels of liquid fuel reductions are significant enough to justify the life cycle costs of a PV system. This type of arrangement offers the highest potential for a PV system to reduce liquid fuels used by generators. For example, if a unit utilized 15kW tactical quiet generators and were able to shut down those generators for 4 hours a day by emplacing 15kW PV systems with battery storage, approximately 5 gallons (1.2 gallon per hour[17]) of fuel reduction per generator per day could potentially be achieved.

Second and Third Order Effects

Beyond providing potential fuel reductions associated with generators, there are additional benefits and some drawbacks to utilizing PV systems. Following are just some of those benefits and drawbacks.

Benefits:

- PV systems produce no green house gas emissions.
- PV systems do not produce noise.
- Once the system is paid for, the electricity produced is free (excluding spares and maintenance).
- PV systems require minimal maintenance.
- Reductions in fossil fuel for generators contribute to reductions in fuel convoys for the Army in expeditionary environments.

[16] Chris Bolton, Office of the Project Manager-Mobile Electric Power, email message to the authors, 28 February 2010.

[17] Derived from briefing from Project Manager-Mobile Electric Power, "Tactical Electric Power Overview", Army Science Board Brief, 3 March 2010.

Drawbacks:

- Higher initial cost compared to generators.
- Footprint (approximately 100 square feet per kW).
- Inability to easily conceal if necessary.
- PV power is intermittent (depends on adequate sunlight and capacity of battery storage system).
- Additional material will be required for deployment (PV system components).
- Additional training in the employment and use of PV systems will be required for Army personnel.

Cost Information (high level only)

A multitude of variables can affect the cost of a PV system and its corresponding return on investment (ROI). For example, some areas affecting system costs include architecture selected (with or without a battery system and size of battery system), type of solar panels selected, power level of a PV system, installation location, mounting structures and military specifications for a system. ROI can be affected by such variables as amount of usable sunlight for a given location, the amount of actual load a PV system displaces from a generator, the fully burdened cost of fuel (FBCF) for generators for a specific location and the life cycle cost of a PV system which includes maintenance, training and spares.

A general estimated cost for a fully installed commercial PV system in a commercial market would be in the range of approximately \$10/Watt Peak (Wp)[18]. Without considering bulk discounts or other negotiated parameters, this would translate to approximately \$150,000 for a 15kW system's initial purchase and installation. It could be expected that this price would increase for the types of locations the expeditionary Army operates within; "militarizing" a PV system will undoubtedly add costs to a PV system.

If an analysis were to assume a FBCF of \$15/gallon for fuel for a particular command post and not consider any other factors of a PV system's life cycle cost, it would take approximately 10,000 gallons of displaced fuel to pay for a 15kW system that cost \$150,000. If the desired payback would be 5 years (for example), then approximately an average of 5.5 gallons of fuel would have to be saved per day [$10{,}000 \div (365 \times 5) = 5.48$]. If a PV system could displace 15kW of generated power for 4-6 hours per day (possible usable sunlight time), then saving 5.5 gallons of fuel a day is in the realm of possibility as a typical 15kW

[18] Solar Electricity Global Benchmark Price Indices, June 2010 Survey Results, http://www.solarbuzz.com/SolarIndices.htm, (Accessed 11 June 2010).

Army tactical quiet generator (or three 5kW generators) consumes approximately 1.2 gallons per hour[19].

Preliminary Risk Analysis

The risks identified below represent the most significant risks that can impact fielding of PV systems for the purposes of supplementing tactical level power generation.

Each risk has an associated:

- Probability of occurrence - ranked high, medium or low.
- Impact of occurrence - ranked high, medium or low.
- Mitigation strategy - classified as Avoid, Mitigate, Accept or Transfer.
- Sensitivity area – highest affected area related to Scope, Schedule or Cost.

Risk	Probability of Occurrence	Impact of Occurrence	Mitigation Strategy	Sensitivity Area
1. Adequate funding not made available to continue development of PV system concepts.	High	Medium	Accept	Schedule(s)
2. PV systems do not function as intended (ROI expectations cannot be achieved).	Medium	Medium	Mitigate (by testing in representative environment)	Cost (payback)
3. PV systems cannot be functionally integrated with all major types of existing Army generators.	Medium	Medium	Transfer (by requiring PV system supplier(s) to design appropriate interfaces)	Scope

[19] Derived from briefing from Project Manager Mobile Electric Power, "Tactical Electric Power Overview", Army Science Board Brief, 3 March 2010.

Conclusions and Recommendations

Conclusions

As previously discussed, PV systems can be utilized by the Army in three primary application fashions, which are:

- Option #1 - A PV system used in a stand-alone arrangement without backup generators.
- Option #2 - A PV system connected in parallel to existing power generation equipment **without** a battery or similar storage system.
- Option #3 - A PV system connected in parallel to existing power generation equipment **with** a battery or similar storage system.

The Army could elect to adopt one specific type of application or elect to adopt all three with specific use areas for each. One of the strengths of PV systems is modularity. Individual components can be added or removed to provide specific capability as needs vary.

The benefits of each type application will vary based on the amount of load that can be displaced from an associated generator. The possible amount of load reduction on a generator and corresponding generator liquid fuel reduction varies with each option.

A more detailed analysis must be performed on each option based on the ability to shed load from a generator, down size a generator, or to shut down a generator for short periods of time to determine if the levels of liquid fuel reductions are significant enough to justify the life cycle costs of a PV system.

Recommendations

Procure and test, in a simulated expeditionary command post environment, three different prototypes; one for each option outlined above. Refine designs and requirements as appropriate based on prototype testing. Perform a formal business case on each option based on findings from prototype testing.

To field PV applications in the expeditionary environment, the Army must first develop general requirements and specifications for PV systems for use as a means of supplementing generator produced tactical level power. To fully develop those requirements and specifications and to position the Army to down-select an optimal solution(s), prototypes for each option above should be designed, procured and evaluated in a simulated expeditionary command post environment to validate potential fuel reductions and design parameters for each option. Outcomes from prototype testing should then be utilized to more precisely define and evaluate PV technologies in formal business cases and/or progress with spiral development cycles.

Specific usage recommendations for each configuration option discussed in this document are as follows:

- Option #1 - A PV system used in a stand-alone arrangement without backup generators.
    - *Recommendation:* Use of a PV system in a stand-alone mode is recommended for non-critical loads only.
- Option #2 - A PV system connected in parallel to existing power generation equipment **without** a battery or similar storage system.
    - *Recommendation:* Use of a PV system in parallel with a generator without a battery storage system is generally not recommended for use by the Army on a large scale in the tactical environment. If this arrangement were to be used, it should only be utilized a means of supplementing existing generated power as long as there is no reduction in the rated size of the corresponding generator. The generator should still be sized to support its entire load.
- Option #3 - A PV system connected in parallel to existing power generation equipment **with** a battery or similar storage system.
    - *Recommendation:* Use of a PV system in parallel with a generator with a battery storage system should be the preferred option for the Army. Additionally, if the generator were routinely shut down during use of the PV system, the Army should incorporate an "auto start/stop" feature for the generator to automatically start and stop the generator when the battery system reaches specified levels of storage capacity.

ANNEX C – AUTOMATED DATA COLLECTION FOR FUEL AND ENERGY MANAGEMENT, TO APPENDIX F – PRELIMINARY BUSINESS CASE ANALYSES

This preliminary business case analysis addresses the development of an automated data collection capability that gives Soldiers and leaders a means to measure, monitor and control tactical fuel and energy supply and demand, systems performance, and inform decisions and actions regarding the prioritization and allocation of energy resources.

Problem Statement, Current State, Objective and Scope

Problem Statement

Detailed data on fuel usage and energy consumption does not exist in the tactical environment. For Soldiers and leaders to make informed decisions related to managing and potentially reducing fuel and energy consumption in the future, they must know and understand the demand (where and how fuel and energy is being consumed).

Current State

Currently, detailed fuel supply data is available that identifies how much fuel the Army has purchased, and what has been delivered to the theater. However, detailed consumption data that depicts how much total fuel the Army actually consumed[1], how much was consumed for a particular military operation or in a specific platform or piece of equipment, or how the fuel is specifically used is not available. In addition, information related to power demand and energy consumption by equipment is also not available. Without sufficient data and the tools to collect that data, Soldiers and leaders at all levels will continue to not have the ability to make informed decisions regarding fuel consumption and power and energy management.

The Defense Science Board (DSB) in a 2008 study noted "effectively managing fuel demand requires an in-depth understanding of the activities that are creating the demand. Unfortunately, data in energy usage are unevenly collected across the Department, making it difficult to form a comprehensive picture."[2] The study goes on to note that for operational systems, the Defense Logistics Agency-Energy (DLA-E) operates an accounting system for the purpose of tracking purchases, but data showing where it is used, for what purpose, and by which end-items are inconsistent. The Air Force keeps excellent records of aircraft fuelings by tail number, quantity, date, and location. Data on use by ground systems are not collected.[3]

[1] The Army purchases fuel that is consumed by other organizations and agencies other than the Army. The Army does not have an efficient method to determine what quantity of the fuel that it purchased was consumed by non-Army elements. See Appendix C of this report for further discussion.
[2] *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DOD Energy Strategy, February 2008, 15.
[3] Ibid.

The Government Accounting Office (GAO) concluded in February 2009, that "By placing a higher priority on fuel reduction at forward-deployed locations and developing a comprehensive and coordinated approach to managing fuel demand, one that includes specific guidelines, …visibility, and accountability, DOD would be more likely to achieve its goals of reducing its reliance on petroleum-based fuel, the vulnerabilities associated with transporting large amounts of fuel to forward-deployed locations, and operational costs."[4] Additionally, TRADOC has identified among several technology-oriented Warfighter Outcomes for expeditionary base camps the need to "establish power management processes and tools to determine, monitor and adjust load demand…"[5]

The DCS G-4, in a 2010 white paper, developed collaboratively with the Army Capabilities Integration Center (ARCIC) and the Research, Development and Engineering Command (RDECOM), identified as the number one power and energy grand challenge the capability to "give Soldiers and leaders a means to manage – measure, monitor and control energy status, usage and system performance: prioritize and redistribute resources. This challenge includes…integration of power and energy management into operational planning and execution…"[6]

To address the challenges identified by the DCS G-4, the shortcomings identified by the DSB and TRADOC, and implement the recommendations of the GAO at the tactical level, the Army needs to develop and field an automated fuels and energy management capability within both the Battle Command and Army Enterprise systems.

Objective

The objective of developing and fielding an automated energy management capability within both the Battle Command and Army Enterprise systems is to provide a capability that:

- Generates, collects and analyzes energy demand and fuel consumption for tactical vehicles, equipment and tactical level base camps.

- Integrates fuel and energy data/information needs into effective automated tools that allow leaders to assess and manage energy demand and use.

- Integrates fuel and energy data/information into an effective automated decision support tool that communicates fuel and energy requirements for a proposed operation and the impacts (risks) of sub-optimal quantities on success.

The TFEIP lays out the following objective for understanding the Army's energy consumption profile:

[4] *Defense Management: DOD Needs to Increase Attention on Fuel Demand Management at Forward-Deployed Locations*, U.S. Government Accountability Office Report to the Subcommittee on Readiness, Committee on Armed Services, House of Representatives, February 2009, 34.
[5] *Power and Energy Strategy White Paper*, Army Capabilities Integration Center – Research, Development and Engineering Command – Deputy Chief of Staff, G4, US Army, 1 April 2010, 9.
[6] Ibid.

- By 2015, integration of effective fuel and energy data collection and analysis tools that allow leadership to assess, manage, and evaluate tactical force energy demand.

In support of that objective, the TFEIP identifies the following tasks:

- By FY14, field a Battle Command integrated solution that permits automated fuel and energy management and planning support up to the ASCC level.

- By FY15, expand this capability to the Army Enterprise enabling tracking, analysis, and high level management of tactical energy, in near real time.

The intent of these tasks is to provide a system that collects energy demand and fuel consumption for tactical equipment and/or base camps with sufficient fidelity to enable effective management of energy at all levels.

Scope of Analysis

This analysis only focuses on the development and use of a data collection system for the tactical base level where no such capability currently exists. It is not the intent of this analysis to evaluate and recommend specific technologies but rather to propose options where none exist.

Major Assumptions and Constraints

Assumptions

The following assumptions are made regarding development, deployment and use of a tactical fuels and energy data collection system:

1. The Army desires to collect fuel consumption and power demand data at the platform level.

2. A method to aggregate data and upload that data to an enterprise system will be necessary.

3. Current legacy enterprise systems can be configured to serve as a repository of collected data and function as an energy management system.

Constraints

The following constraints exist regarding development, deployment and use of a tactical fuels and energy data collection system:

1. Data collection methodologies must not hinder effective operations and mission accomplishment.

2. Data collection devices (if utilized) must be able to withstand harsh environments.

Descriptions and Preliminary Comparison of Alternatives

Various methods exist to collect fuel and energy usage data ranging from manual recording of information to employment of devices that semi-automatically or automatically capture information. Regardless of what method is used to capture the data, the data must ultimately be incorporated into a computerized database and disseminated through an enterprise system for use by the Army at multi-echelons and across commands, organizations, and agencies.

To that end, this analysis will assess options for:

- Information capture related to fuel and energy consumption.
- Enterprise reporting of fuel and energy consumption.

Following is an assessment of each area.

Information Capture (Manual, Semi-Automatic, Automatic)

Manual: Manual information collection involves manually collecting fuel consumption data for tactical vehicles and power generators on paper forms and manually transposing that data to an enterprise accessible data base on a regular frequency. This method would not capture the electrical energy demand placed on power generators. Since power generators use fuel and the amount of fuel they use is a function of how much power they produce, only collecting fuel consumption data for power generators and not energy usage may suffice for the Army. This method, however, is subject to human error during data collection and transposing and could be somewhat labor intensive depending on the frequency of updating information and the amount of data to be collected.

Fuel consuming platforms such as tactical vehicles and power generators all carry unique identifiers. Anytime those platforms are re-fueled, the type and amount of fuel could be recorded for each specific platform which would provide the Army with greater detail than what is currently available today. This, among other things, could provide Army personnel with the ability to assess trends in fuel consumption and identify where opportunities exist to reduce fuel consumption.

Utilizing paper forms to collect data comes with its share of issues. For instance, forms can get misplaced, written information can be illegible, fuel would not be denied if forms and writing instruments were not available, and forms could be incompletely or incorrectly filled out; each resulting in incomplete and/or inaccurate data being available.

Semi-Automatic: Semi-automating the process of capturing data would increase the accuracy of the collected data and reduce the labor associated with collecting and inputting that data into a database. For example, use of bar coding and hand held scanning devices with operator inputting capability could eliminate the need for paper forms as well as reduce

the amount of labor associated with capturing and transposing data. This would require emplacing barcodes on all fuel consuming devices and the purchase of hand held scanners. An example of a hand held bar code scanner with operator input features is depicted in Figure #1.

Symbol MC3090 Series

Figure 1

Use of devices such as these allow for semi-automatic input of data into the scanner based on scanning a bar code. The bar code could identify the ID number for a particular piece of equipment when the bar code is scanned. Once scanned, fields in the scanner could automatically populate with date and time and prompt the person scanning to enter additional information such as gallons of fuel put in the equipment, type of fuel, odometer or hour meter readings if desired and available, and any other variable information deemed important. The information could then be stored in the scanner until the scanner could be "cradled" into a data up-loading device connected to a local networked computer. Devices such as these are widely used in commercial industry and can range in cost from several hundred dollars to a couple thousand dollars each depending on the features and accessories desired[7].

Emplacing a barcode on equipment could be accomplished during routine maintenance cycles. Most likely, the medium for the barcode would have be a substrate that would withstand harsh environments and be placed in a location on the equipment in a somewhat protected manner.

Beyond collecting fuel usage data, simple low cost devices could be utilized to record energy consumption (such as power) in areas of large consumption if the Army deemed that data beneficial. For example, power generators are the single largest fuel consumers on the battlefield accounting for approximately 34% of the fuel consumed[8]. Utilizing simple low cost watt-hour meters in strategic applications could provide sufficient additional detail to

[7] Cost range based on random sampling of scanners on the internet without quantity discounts.
[8] Derived from table in *More Fight – Less Fuel*, Report of the Defense Science Board Task Force on DoD Energy Strategy, February 2008, 44.

enable assessment of energy consumption by area (i.e. billeting, dining, motor poll, etc.). An example of a low cost (<$300[9]) watt-hour meter is depicted in Figure #2.

The Mini Meter OEM Module is housed in an outdoor, NEMA 4X, UL Listed enclosure, with an electro-mechanical counter indicating kWh usage installed in the enclosure door. The enclosure has room for an RF transmitter for automatic meter reading.

Figure 2

Installation of devices such as these could (for example) provide Army personnel with the capability to assess power consumption trends and adjust load connections to maximize use of existing power generators; thus reducing fuel.

NOTE: Installing watt-hour meters should be considered in light of the Army installing intelligent micro-grids (potential future initiatives). Intelligent micro-grids could (if designed to) include capability to monitor and report power consumption by connected load groups which could take the place of meters such as these.

Maturity of Solution: Hand held bar code scanners (if utilized) are well developed and readily available in ruggedized versions. Given the price ranges of hand held bar code scanners, it is not envisioned that "militarizing" scanners for use in the expeditionary environment will be necessary. Most likely it would be more cost effective to replace damaged scanners rather than initially paying the up-front extra cost to "militarize" the devices. Watt-hour meters (if utilized) are also well developed and are available in enclosures suited for harsh environments. Installation of such meters on-site would require qualified electrical personnel.

Automatic: Automating the process of capturing data would provide for the maximum accuracy of the collected information and the minimum labor associated with capturing that information. In addition, for fuel consumption, automation could also incorporate levels of security to ensure that only authorized fuel consuming platforms receive fuel; thus minimizing fraudulent fuelings.

Various methods exist to automate data collection for fuel consumption. The most predominant method used in commercial industry employs the use of Radio Frequency Identification (RFID) tags (see Figure #3) applied to vehicles/equipment coupled with RFID receivers located on fuel dispensing equipment. Similar to a bar code, a RFID tag located on

[9] Price based on http://www.powermeterstore.com/p6801/ims_minimeter_outdoor.php, (Accessed 16 August 2010). Price does not include installation costs.

a fuel consuming platform could identify the ID number for a particular piece of equipment (as well as other data). The RFID tag would automatically transmit its data to the receiver when the tag and receiver come in close proximity to each other; eliminating the need for manual scanning. The fuel dispensing nozzle could also contain a RFID tag (see Figure #3) to identify the specific fueling nozzle (which could determine the type of fuel) and transmit that data as well. The receiver could be connected to a local site controller for transmitting information to a local computer.

Depending on the capabilities of the fuel dispensing device, some data may still have to be manually entered into the local site controller. Specifically, manual input of gallons dispensed may have to be entered into the controller via a key pad on the controller if the dispensing device does not provide an electronic capability for capturing gallons dispensed.

Wireless Nozzle ID **RFID Tag**

Figure 3

RFID tags can range in cost from $20-$70 each[10] depending on packaging and quantities purchased. Each fuel consuming platform would require only one tag. RFID receivers can range in cost from $500-$2,000 each[11] depending on features in the device, packaging and quantities purchased.

Capturing data for power consumption could also be achieved automatically. As noted in previous Figure #2, watt-hour meters can be fitted with Radio Frequency (RF) transmitters to automate meter readings.

Maturity of Solution: Wireless RFID tags and receivers are well developed and readily available in ruggedized versions. Installation of RFID receivers for fueling stations would require qualified electrical personnel. Watt-hour meters can be purchased with RF transmitters incorporated but would require qualified electrical personnel to install the meter itself.

[10] Price range based on http://www.rfidinc.com/tutorial.html, (Accessed 26 August 2010).
[11] Price range based on http://www.rfidjournal.com/faq/20/86 (Accessed 26 August 2010). Does not include installation costs.

Enterprise Reporting

Once data on fuel and energy consumption are collected (either manually, semi-automated, or automated), it must be aggregated, incorporated into a database, transmitted and be available to higher headquarters (up to the ASCC and HQDA) for assessment and managerial oversight. The proposed solution should use the Army's Battle Command System for data transmission, which should then be centrally archived for analytical purposes by Army Enterprise systems.

The Fuels Manager Defense (FMD) module of Defense Logistics Agency's (DLA) Business Systems Modernization-Energy (BSM-E) is one example of a potential fuels and energy accounting tool that could be configured and utilized for reporting and analysis purposes. FMD provides the ability to maintain asset visibility of petroleum quantities across the full spectrum of operations with the following capabilities:

- Track consumption to the individual vehicle/weapons system.
- Automated source data collection and integration capability from automated tank gauges, temperature compensating meters, and automated and manual data input devices.
- Provide a mechanism for specialized customer support through customized terminal interfaces which allow user-generated database queries on accounts.
- Use telecommunications assets that promote real-time or near real-time data processing.

Information from FMD could be interfaced with the Battle Command Sustainment Support System (BCS3) to achieve enterprise wide accessibility and reporting.

Maturity of Solution: Modification of FMD and interfacing with BCS3 will be required. The Army currently has the capability, either internally or thru contract suppliers, to achieve this.

Preliminary Risk Analysis

No risks are anticipated with implementation of a tactical fuels and energy data collection system.

Conclusions and Recommendations

Conclusions

Currently, detailed fuel supply data is available that identifies how much fuel the Army has purchased, and what has been delivered to the theater. However, detailed consumption data that depicts how much total fuel the Army actually consumed, how much was consumed for a particular military operation or in a specific platform or piece of equipment, or how the fuel is specifically used is not available. In addition, information related to power demand and energy consumption by equipment is also not available. Without sufficient data and the tools to collect that data, Soldiers and leaders at all levels will continue to not have the ability to make informed decisions regarding fuel consumption and power and energy management.

Collecting data related to tactical fuels and energy consumption in itself will not control or reduce fuel consumption for the Army. Data will however facilitate informed assessments and better decision making leading to better control of and possible reductions in fuel and energy consumption.

Various methods exist to collect data ranging from manual recording of information to employment of readily available devices such as hand-held bar code scanners that semi-automatically capture information to fully automating data collection thru use of RFID technologies. Regardless of what method is used to capture the data, the data must ultimately be incorporated into a computerized database and disseminated through an enterprise system for use by the Army at multi-echelons and across commands, organizations, and agencies.

Recommendation

Recommend that the Army conduct a formal business case analysis to determine the following:

A. The level of detail of fuel consumption and energy demand data that provides the Army the desired capability.

B. The most effective data collection methodologies that reduce/eliminate errors and provide real time/near-real time data compilation and analysis.

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APPENDIX G - ACRONYMS, ABBREVIATIONS, TERMS, AND DEFINITIONS

ACC	Army Capstone Concept
ACOM	Army Command
AESIS	Army Energy Security Implementation Strategy
AESTF	Army Energy Security Task Force
AIS	Automated Information System
Alternative Energy	Energy derived from any source other than fossil fuels. Alternative energy need not be renewable.
AMC	Army Materiel Command
AMMPS	Advanced Medium Mobile Power Source
AMSAA	Army Material Systems Analysis Activity
AO	Area of Operations
AOR	Area of Responsibility
ARCENT	U.S. Army Central
ARCIC	Army Capabilities Integration Center
ASA	Assistant Secretary of the Army
ASA (ALT)	Assistant Secretary of the Army for Acquisition, Logistics & Technology
ASA (I&E)	Assistant Secretary of the Army for Installations & Environment
ASCC	Army Service Component Command
ATEC	Army Test and Evaluation Command
BCT	Brigade Combat Team
BCS3	Battle Command Sustainment Support System
BFV	Bradley Fighting Vehicle

BSM-E	Business System Modernization-Energy
C2	Command and Control
CDD	Capability Development Document
CERDEC	Communications-Electronics Research, Development, and Engineering Center
CID	Criminal Investigation Division
COCOM	Combatant Command
COP	Combat Outpost
COTS	Commercial Off The Shelf
CP	Command Post
CPD	Capability Production Document
DA	Department of the Army
DASA (E&P)	Deputy Assistant Secretary of the Army for Energy & Partnerships
DFSP	Defense Fuel Supply Point
DLA	Defense Logistics Agency
DLA-E	Defense Logistics Agency-Energy
DOD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities
DRU	Direct Reporting Unit
DSB	Defense Science Board
ECU	Environmental Control Unit
EDI	Electronic Data Interchange
EE PEG	Equipping Program Evaluation Group

EMI	Electromagnetic Interference
Energy	Any usable power, including but not limited to coal, petroleum products, steam, electricity, natural gas, propane, military operational fuels and propellants, alternative fuels and renewable energy, including, but not limited to, synthetic and biomass-derived fuels, solar, wind, geothermal, and nuclear, but excluding nuclear energy used in ship propulsion.
ESG	Energy Security Goal
ESO	Energy Security Objective
EXCOM	Executive Committee
FBCF	Fully Burdened Cost of Fuel
FMD	Fuels Manager Defense
FMTV	Family of Medium Tactical Vehicles
FORSCOM	Forces Command
FY	Fiscal Year
GAO	Government Accountability Office
GCV	Ground Combat Vehicle
GPS	Global Positioning System
HEMTT	Heavy Expanded Mobility Tactical Truck
HI-Power	Hybrid Intelligent Power
HMMWV	High Mobility Multi-Purpose Wheeled Vehicle
HQDA	Headquarters, Department of the Army
DCS G-4	Deputy Chief of Staff of the Army, G-4/Logistics
IA	Implementing Activity
IECU	Improved Environmental Control Unit

Implementation Activity	A defined work effort, work element, task, step or action performed that is focused on helping to accomplish an objective.
IPERC	Intelligent Power & Research Corporation
IPT	Integrated Product Team
ITV	In-Transit Visibility
JCIDS	Joint Capabilities Integration Development System
JLTV	Joint Light Tactical Vehicle
JOE	Joint Operating Environment
JROC	Joint Requirements Oversight Council
JROCM	Joint Requirements Oversight Council Memorandum
JP-8	Jet Propellant 8 (military-grade, kerosene-based jet fuel)
KFA	Key Fleet Attribute
Key Performance Parameter	Those attributes or characteristics of a system that are considered critical or essential to the development of an effective military capability. A key performance parameter normally has a threshold, representing the required value, and an objective, representing the desired value.
KPP	Key Performance Parameter
KSA	Key System Attribute
kW	Kilowatt
NSRDEC	Natick Soldier Research, Development, and Engineering Center
OCR	Office of Coordinating Responsibility
OCE	Office of the Chief of Engineers
ODASA (E&P)	Office of the Deputy Assistant Secretary of the Army for Energy and Partnerships
OEF	Operation Enduring Freedom

OIF	Operation Iraqi Freedom
OMS/MP	Operational Mode Summary/Mission Profile
Operational Energy	The energy required for training, moving, and sustaining military forces and weapons platforms for military operations. The term includes energy used by tactical power systems and generators and weapons platforms. (FY09 National Defense Authorization Act)
OPR	Office of Primary Responsibility
OSD	Office of the Secretary of Defense
PDISE	Power Distribution Illumination System-Electric
P&E	Power and Energy
PM-MEP	Project Manager – Mobile Electric Power
POM	Program Objective Memorandum
POS	Peacetime Operating Stocks
PPBE	Planning, Programming, Budgeting and Execution
PV	Photovoltaic
PWRMS	Prepositioned War Reserve Material Stocks
RDEC	Research, Development, and Engineering Center
RDECOM	Research, Development, and Engineering Command
Renewable Energy	Energy generated from resources that are unlimited, rapidly replenished or naturally renewable such as wind, water, sun, wave and refuse, and not from the combustion of fossil fuels.
REPOL	Bulk Petroleum Contingency Report
REPPS	Rucksack Enhanced Portable Power System
RF	Radio Frequency
RFID	Radio Frequency Identification
ROI	Return on Investment

S&T	Science & Technology
SCoE	Sustainment Center of Excellence
SEC	Senior Energy Council
SEE	Senior Energy Executive
S-MOD	Stryker Modernization
STAMIS	Standard Management Information System
TARDEC	Tank Automotive Research, Development, and Engineering Center
TFEIP	Tactical Fuel and Energy Implementation Plan
TFEIP WG	Tactical Fuel and Energy Implementation Plan Working Group
TOP	Test Operating Procedure
TRADOC	Training and Doctrine Command
TRL	Technical Readiness Level
TQG	Tactical Quiet Generator
USAF	United States Air Force
Wp	Watt Peak – Defined as the watt power output of a solar module when it is illuminated under standard conditions of 1000 watts/square meter sunlight intensity, 25°C ambient temperature and a spectrum that relates to sunlight that has passed through the atmosphere (Air Mass 1.5)[1].
WTE	Waste-to-Energy

[1] Glossary of Solar Energy Terms, http://www.solarbuzz.com/consumer/Glossary3.htm#W, (Accessed 15 June 2010).

APPENDIX H – REFERENCES

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